South Puget Sound Dissolved Oxygen Study

Circulation Modeling Status

Mindy Roberts, Anise Ahmed, Skip Albertson, Greg Pelletier

May 20, 2009 Briefing for Advisory Committee

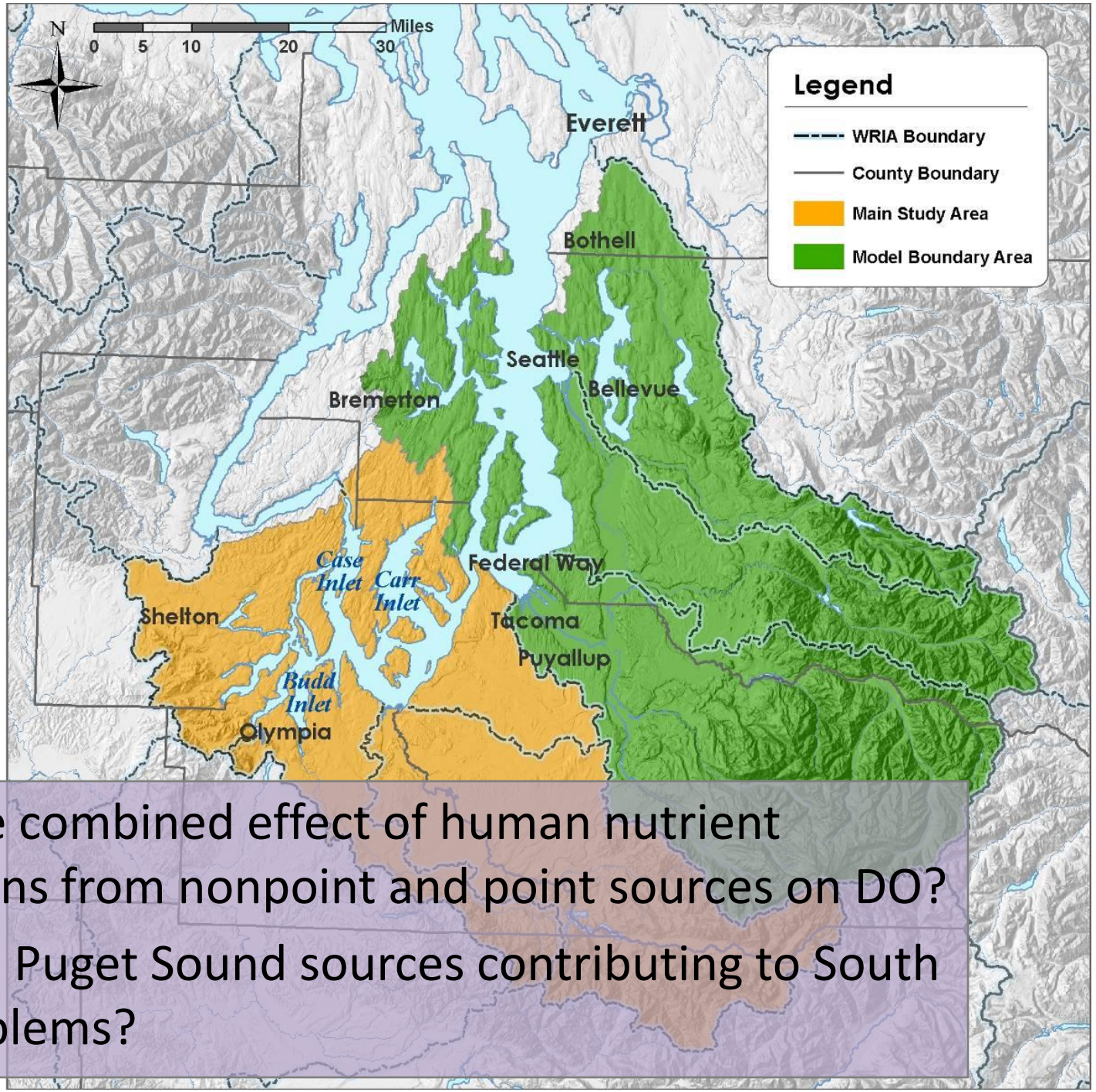
What we cover

1. Project overview
2. Data report status
3. Hydrodynamic model and report development
4. Upcoming steps
   - Water quality model development
   - Scenarios
   - Advisory Committee
   - Final report

Model status

- Much progress
- Circulation model is not quite calibrated
  - Exchange through the Tacoma Narrows is problematic
- Developing tools for assessing influence of Central Puget Sound (and South Sound) sources
- No absolute answers today

Study area

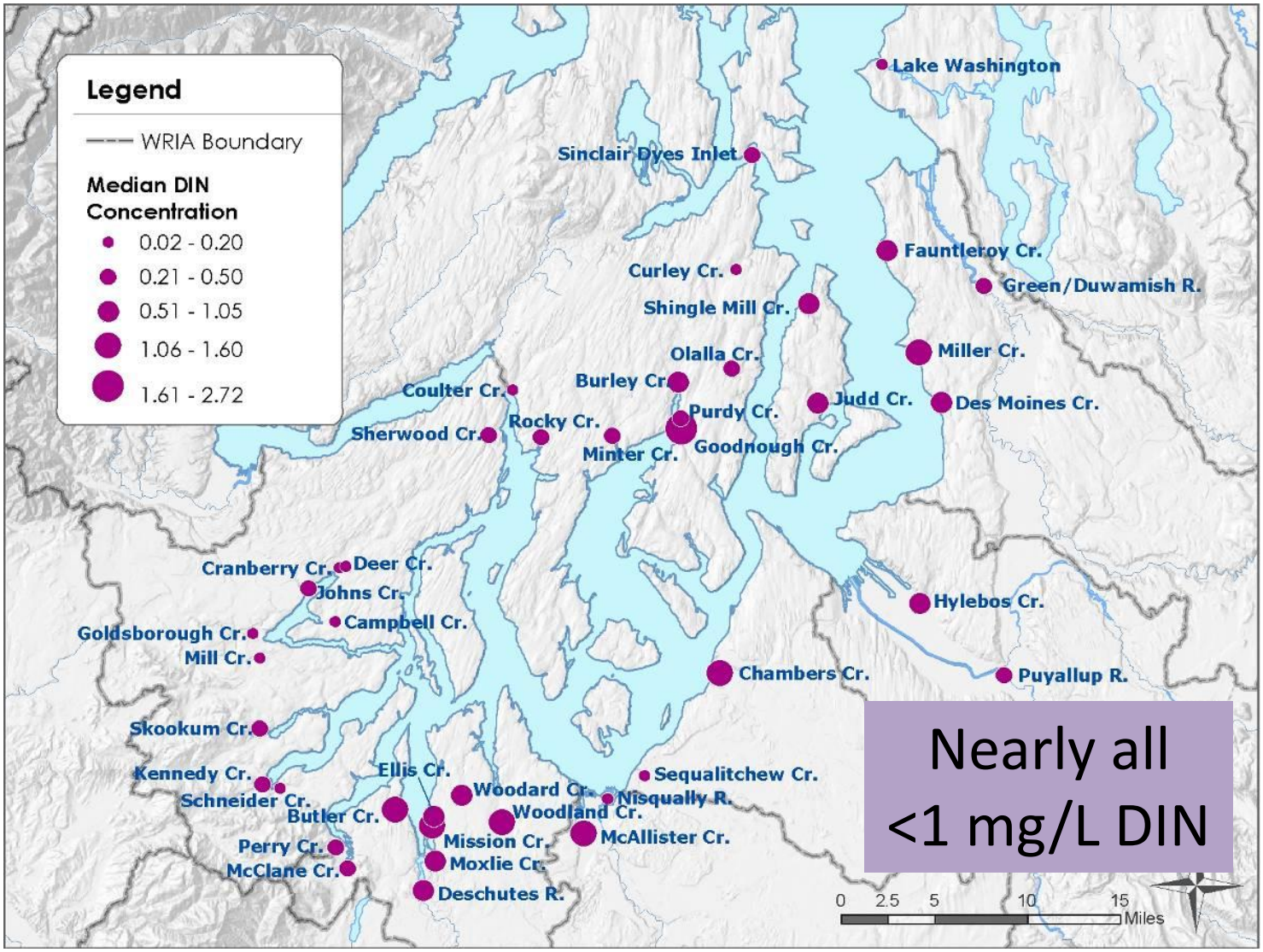


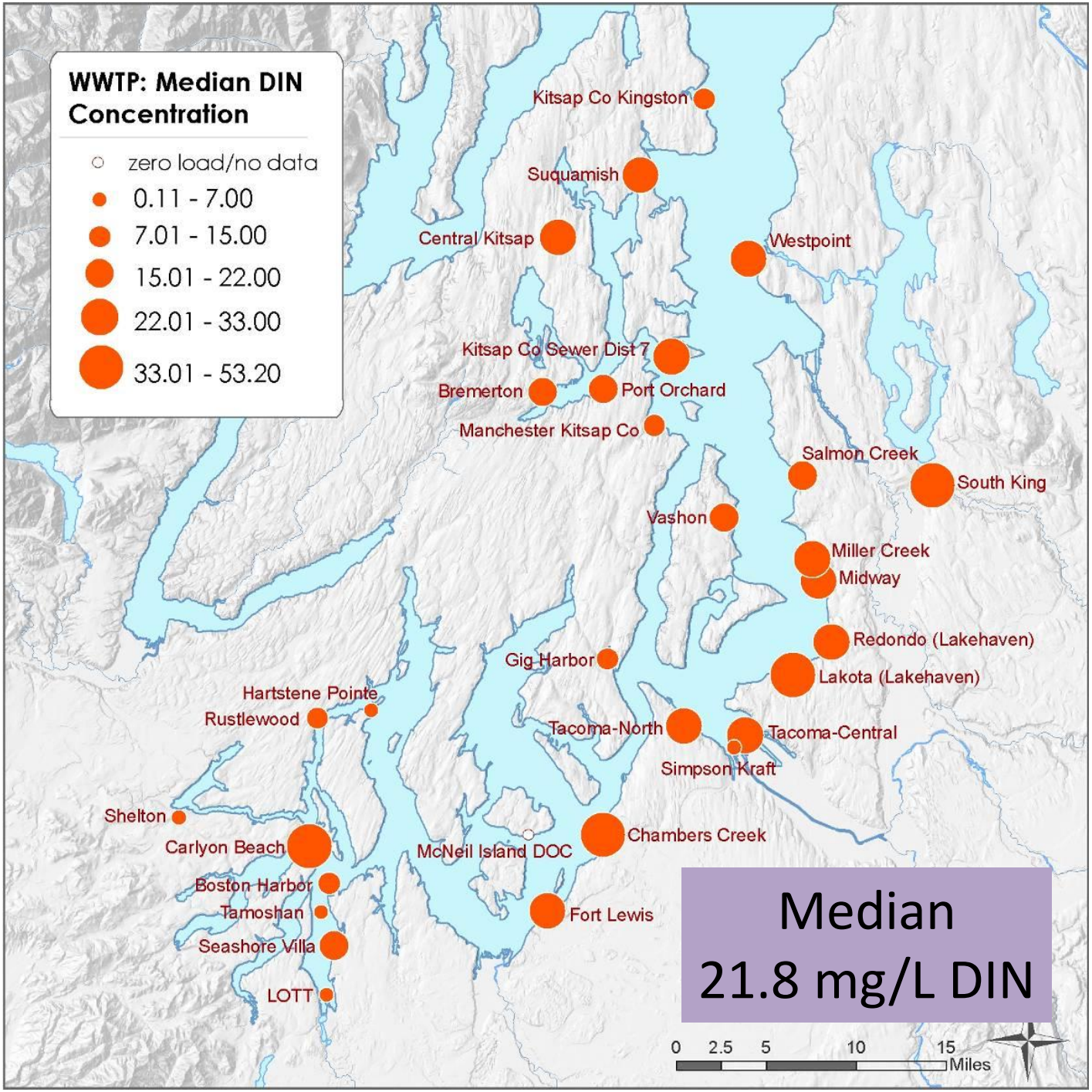
1. What is the combined effect of human nutrient contributions from nonpoint and point sources on DO?
2. Are Central Puget Sound sources contributing to South Sound problems?

Project components

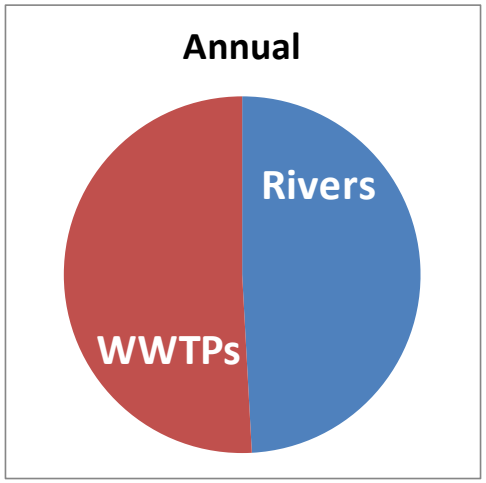
- Data collection
- Circulation model
- Water quality model
- Scenarios
- Reports
  - Data (done)
  - Circulation (pending)
  - Water quality (winter)

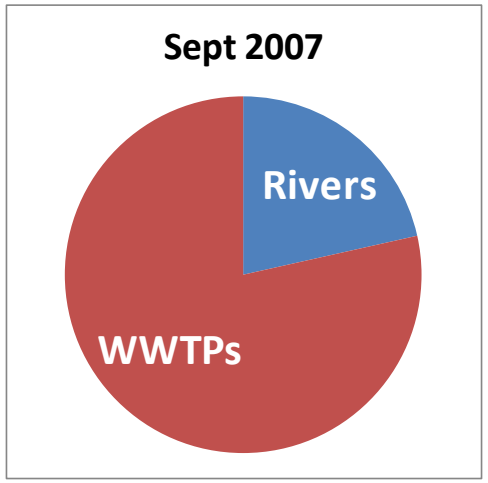
River and stream concentrations

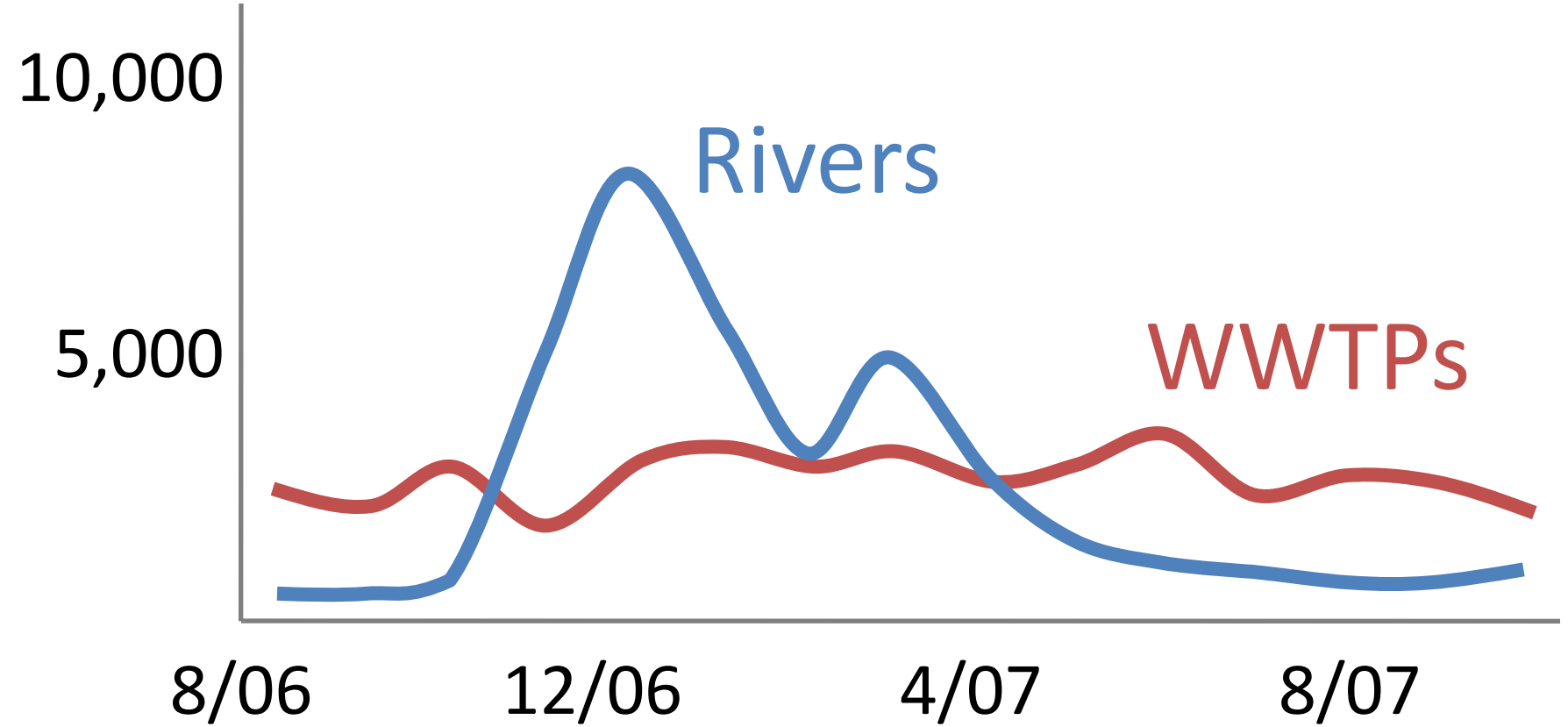



WWTP: Median DIN Concentration
zero load/no data
0.11 - 7.00
7.01 - 15.00
15.01 - 22.00
22.01 - 33.00
33.01 - 53.20
Kitsap Co Kingston
Suquamish
Central Kitsap
Westpoint
Kitsap Co Sewer Dist 7
Bremerton
Port Orchard
Manchester Kitsap Co
Salmon Creek
South King
Vashon
Miller Creek
Midway
Redondo (Lakehaven)
Gig Harbor
Lakota (Lakehaven)
Hartstene Pointe
Rustlewood
Tacoma-North
Tacoma-Central
Simpson Kraft
Shelton
Carlyon Beach
Chambers Creek
McNeil Island DOC
Boston Harbor
Tamoshan
Fort Lewis
Seashore Villa
LOTT
Median
21.8 mg/L DIN
0 2.5 5 10 15
Miles

DIN Load (kg/d)

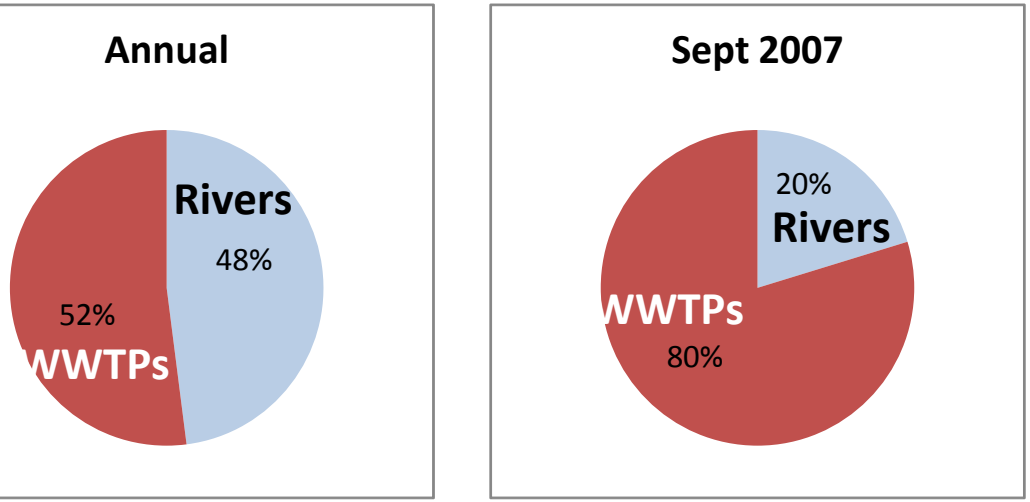

Annual
Rivers
WWTPs

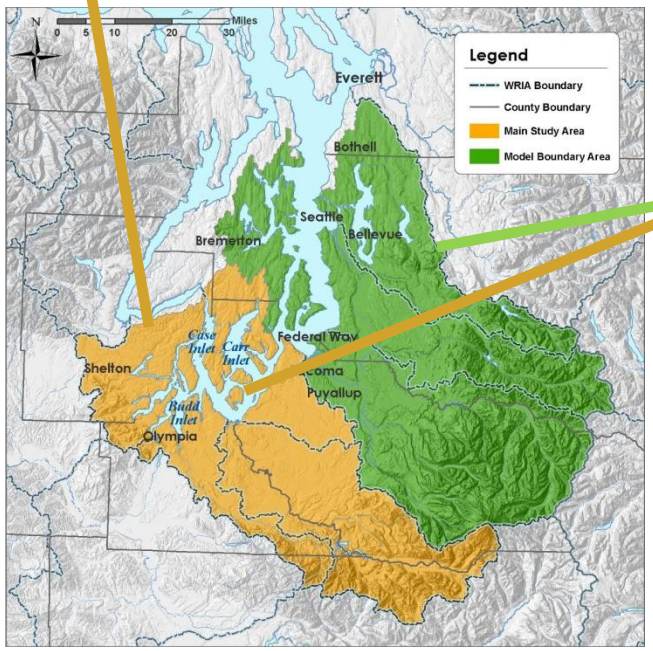

Sept 2007
Rivers
WWTPs


10,000
5,000
Rivers
WWTPs
8/06
12/06
4/07
8/07

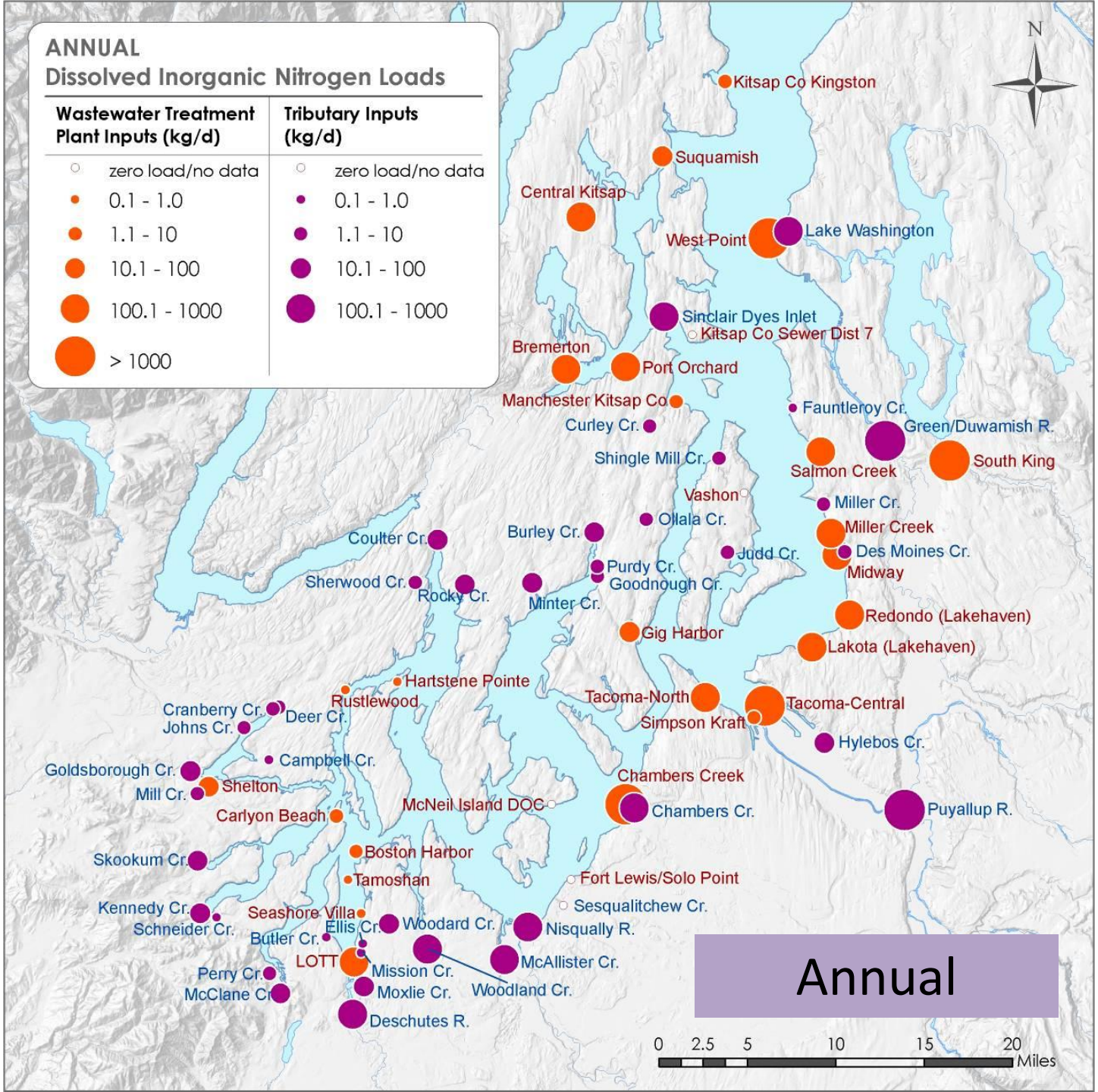
Nutrient sources

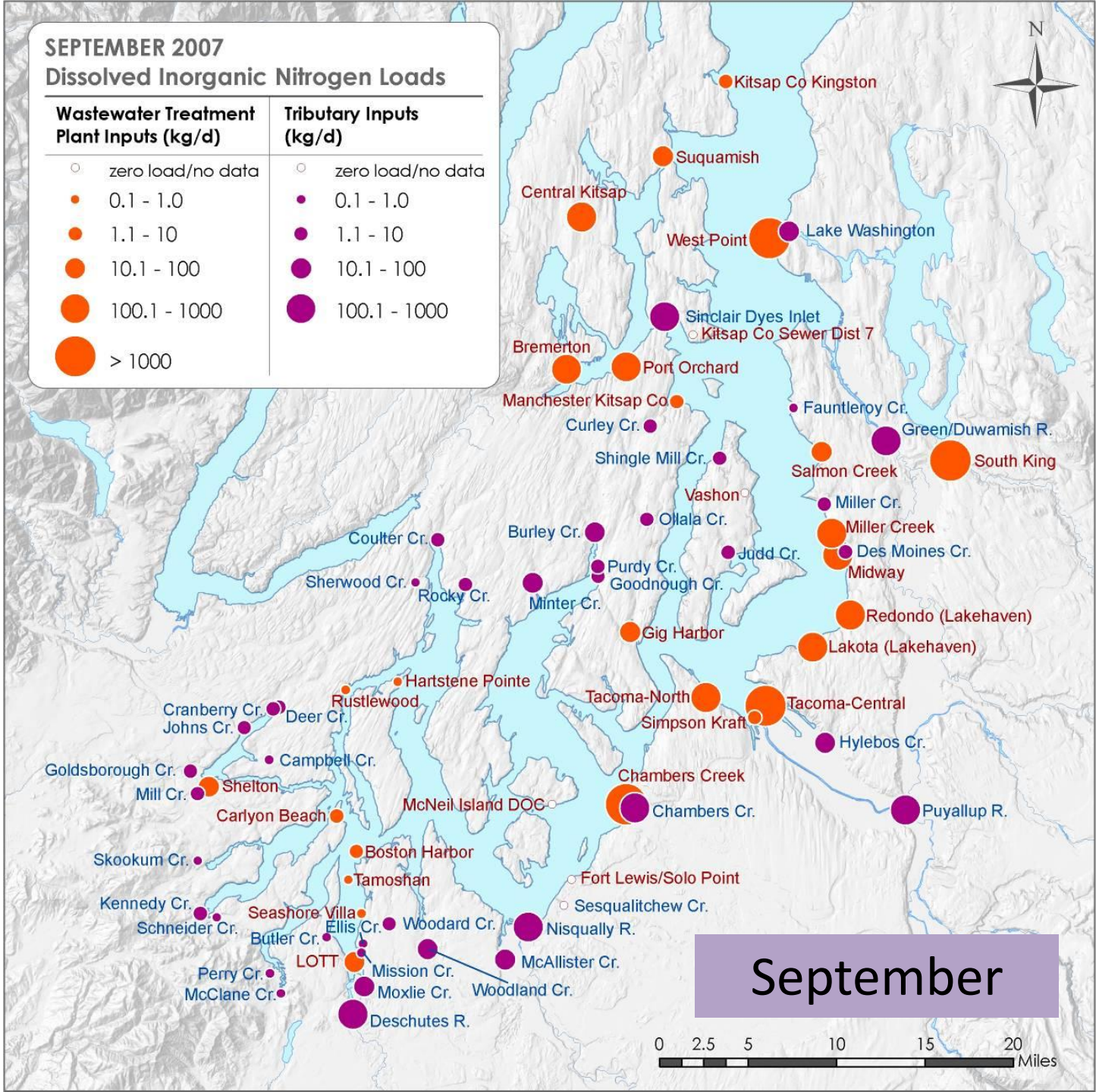
South Puget Sound (south of Tacoma Narrows)





South and Central Puget Sound (south of Edmonds)


ANNUAL
Dissolved Inorganic Nitrogen Loads
Wastewater Treatment Plant Inputs (kg/d)
zero load/no data
0.1 - 1.0
1.1 - 10
10.1 - 100
100.1 - 1000
> 1000
Tributary Inputs (kg/d)
zero load/no data
0.1 - 1.0
1.1 - 10
10.1 - 100
100.1 - 1000
N
Kitsap Co Kingston
Suquamish
Central Kitsap
West Point
Lake Washington
Sinclair Dyes Inlet
Kitsap Co Sewer Dist 7
Bremerton
Port Orchard
Manchester Kitsap Co
Fauntleroy Cr.
Curley Cr.
Green/Duwamish R.
Shingle Mill Cr.
Salmon Creek
South King
Vashon
Miller Cr.
Ollala Cr.
Miller Creek
Burley Cr.
Coulter Cr.
Judd Cr.
Des Moines Cr.
Purdy Cr.
Midway
Sherwood Cr.
Goodnough Cr.
Rocky Cr.
Minter Cr.
Redondo (Lakehaven)
Gig Harbor
Lakota (Lakehaven)
Hartstene Pointe
Rustlewood
Tacoma-North
Tacoma-Central
Cranberry Cr.
Deer Cr.
Johns Cr.
Simpson Kraft
Hylebos Cr.
Campbell Cr.
Goldsborough Cr.
Chambers Creek
Shelton
Mill Cr.
McNeil Island DOC
Chambers Cr.
Puyallup R.
Carlyon Beach
Boston Harbor
Skookum Cr.
Tamoshan
Fort Lewis/Solo Point
Sesqualitchew Cr.
Kennedy Cr.
Seashore Villa
Schneider Cr.
Ellis Cr.
Woodard Cr.
Nisqually R.
Butler Cr.
LOTT
McAllister Cr.
Mission Cr.
Perry Cr.
Woodland Cr.
McClane Cr.
Moxlie Cr.
Deschutes R.
Annual
0 2.5 5 10 15 20
Miles


SEPTEMBER 2007
Dissolved Inorganic Nitrogen Loads
Wastewater Treatment Plant Inputs (kg/d)
zero load/no data
0.1 - 1.0
1.1 - 10
10.1 - 100
100.1 - 1000
> 1000
Tributary Inputs (kg/d)
zero load/no data
0.1 - 1.0
1.1 - 10
10.1 - 100
100.1 - 1000
N
Kitsap Co Kingston
Suquamish
Central Kitsap
West Point
Lake Washington
Sinclair Dyes Inlet
Kitsap Co Sewer Dist 7
Bremerton
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Fauntleroy Cr.
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Salmon Creek
South King
Vashon
Miller Cr.
Ollala Cr.
Miller Creek
Burley Cr.
Coulter Cr.
Judd Cr.
Des Moines Cr.
Purdy Cr.
Midway
Sherwood Cr.
Goodnough Cr.
Rocky Cr.
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Redondo (Lakehaven)
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Cranberry Cr.
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Chambers Creek
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Carlyon Beach
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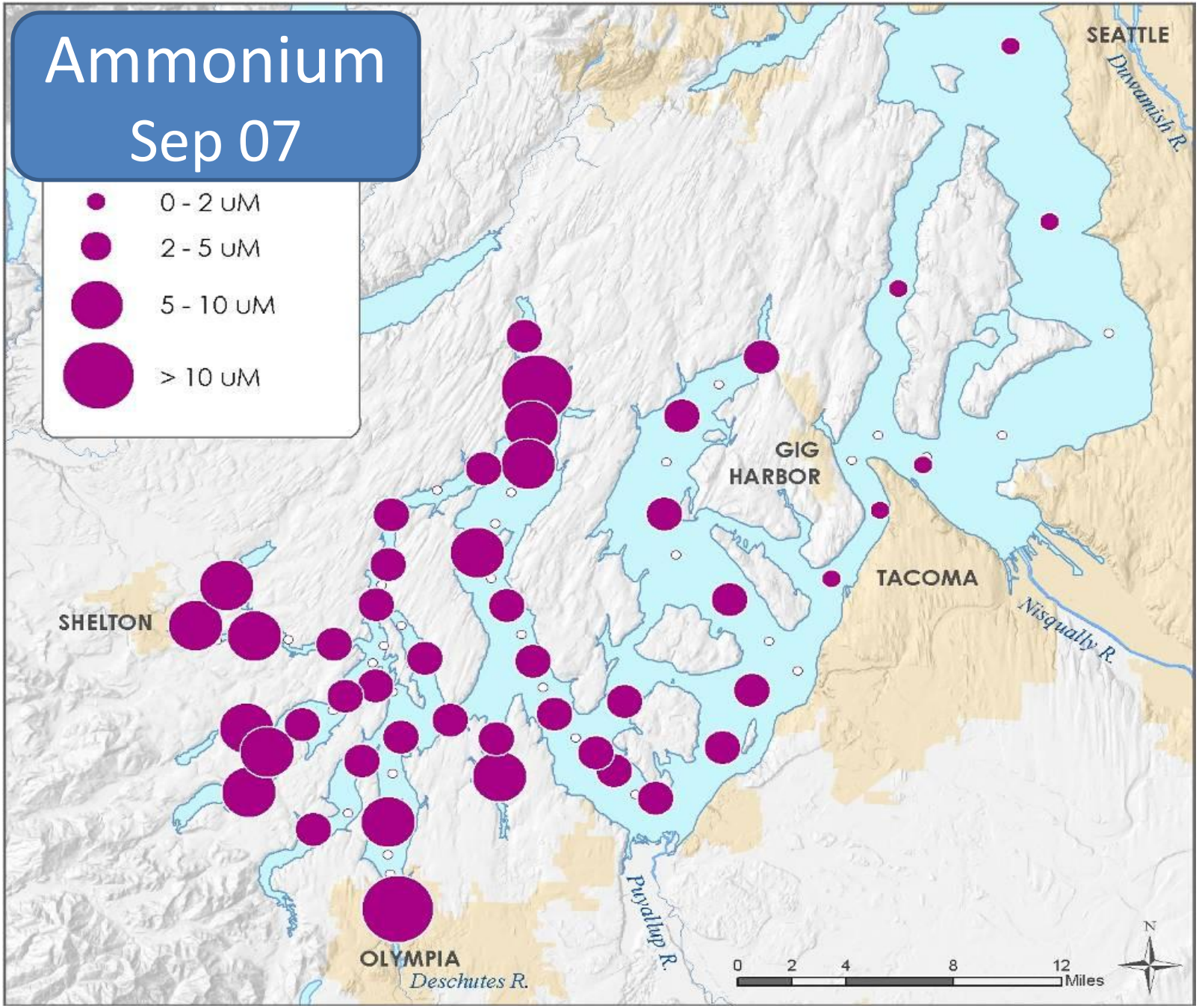
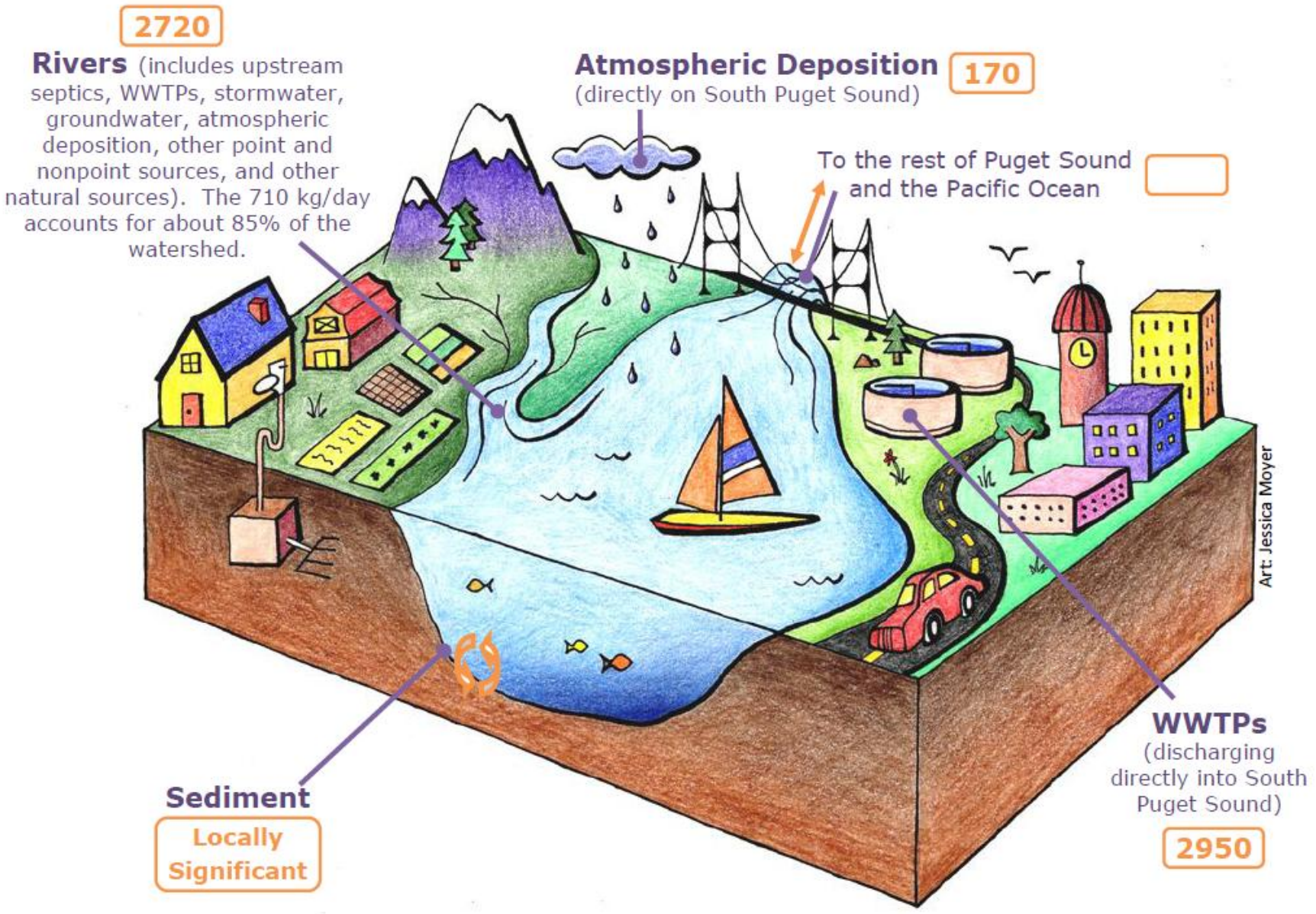
Seashore Villa
Schneider Cr.
Ellis Cr.
Woodard Cr.
Nisqually R.
Butler Cr.
LOTT
McAllister Cr.
Perry Cr.
Mission Cr.
Woodland Cr.
McClane Cr.
Moxlie Cr.
Deschutes R.
September
0 2.5 5 10 15 20
Miles

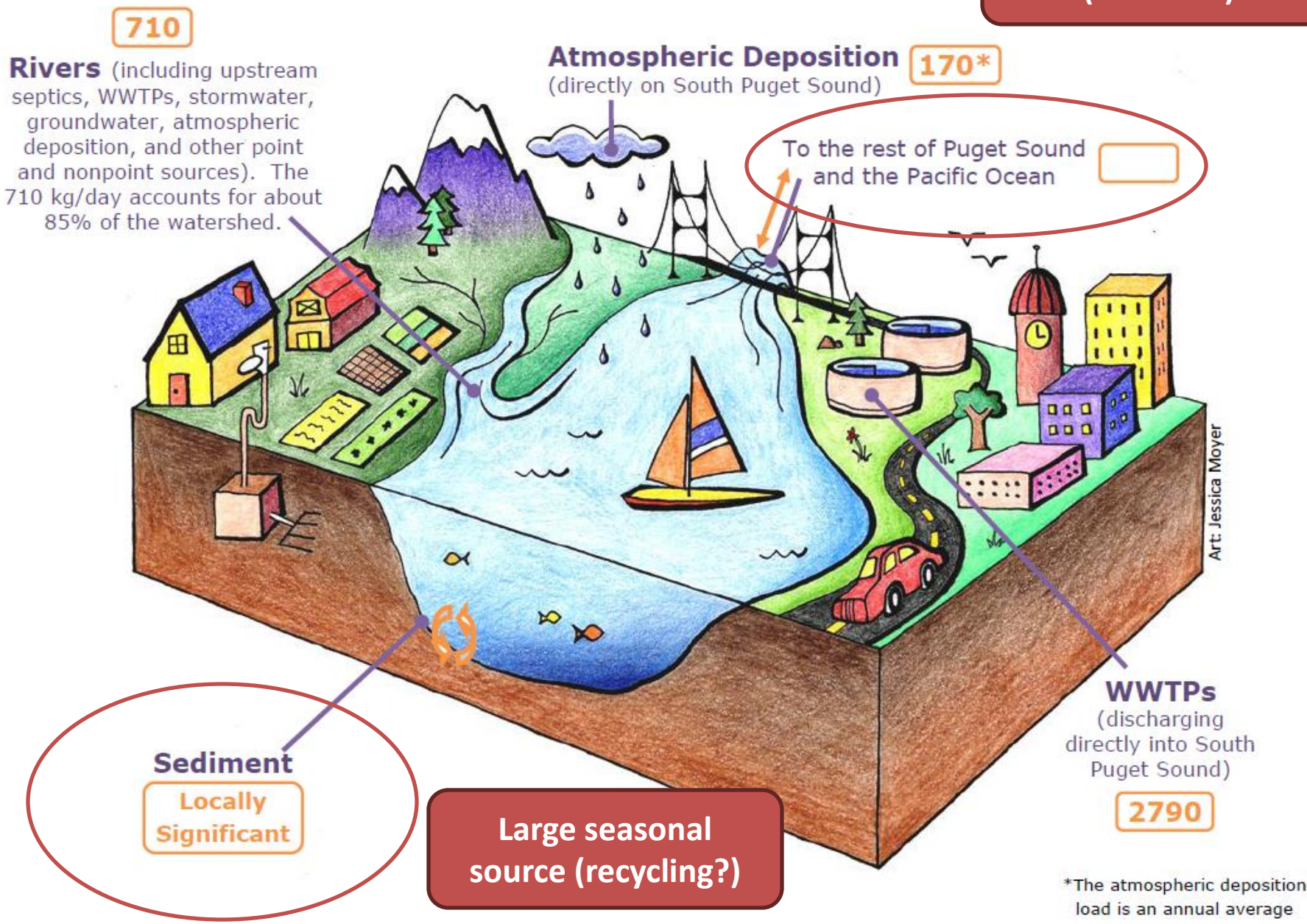

Ammonium
Sep 07
0 - 2 uM
2 - 5 uM
5 - 10 uM
> 10 uM
SEATTLE
Duwamish R.
GIG
HARBOR
TACOMA
Nisqually R.
SHELTON
OLYMPIA
Deschutes R.
Puyallup R.
0 2 4 8 12
Miles
N

Annual


2720
Rivers (includes upstream septics, WWTPs, stormwater, groundwater, atmospheric deposition, other point and nonpoint sources, and other natural sources). The 710 kg/day accounts for about 85% of the watershed.
Atmospheric Deposition
(directly on South Puget Sound)
170
To the rest of Puget Sound and the Pacific Ocean
Art: Jessica Moyer
WWTPs
(discharging directly into South Puget Sound)
2950
Sediment
Locally Significant

September

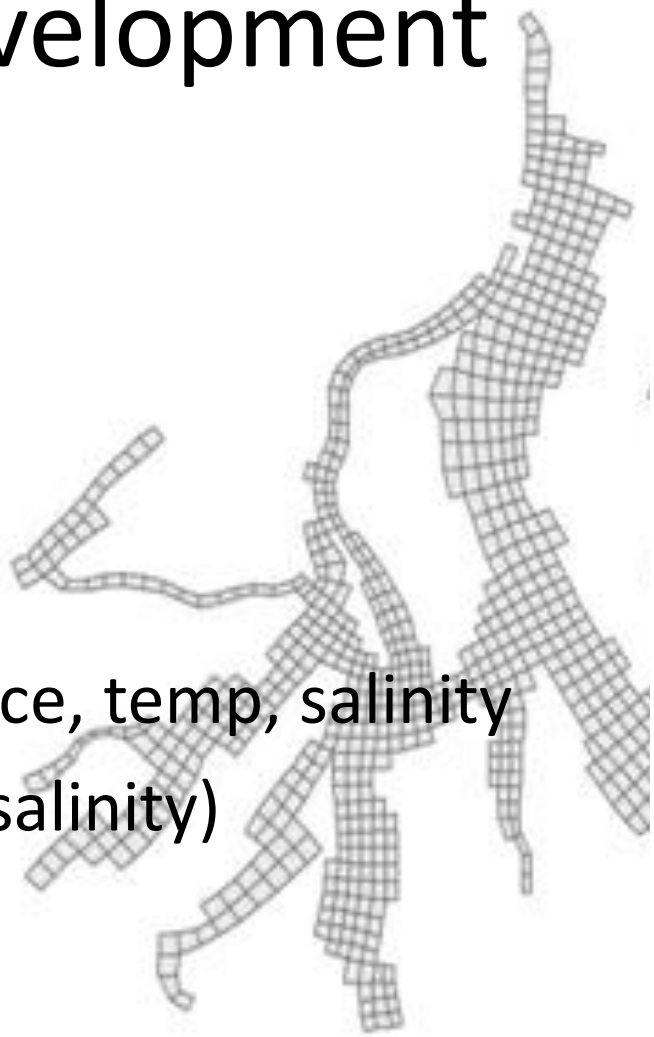
Model-derived value (dilution?)



*The atmospheric deposition load is an annual average

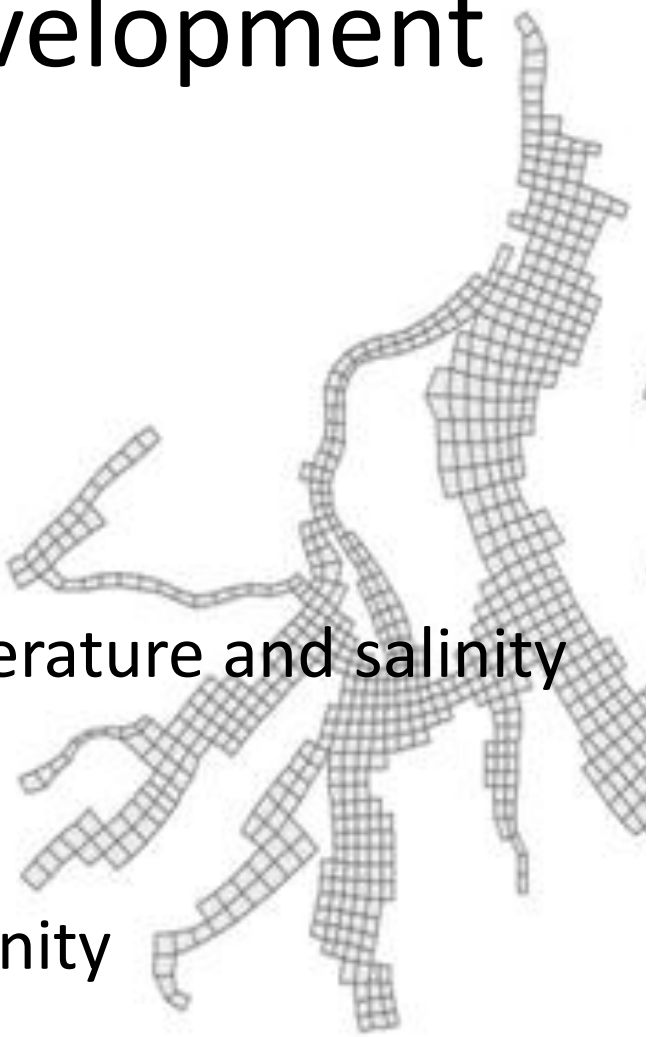
Circulation model development

- Build grid
  - Horizontal grid cells
  - Vertical layers
- Boundary conditions
  - Northern boundary water surface, temp, salinity
  - River flows, temperature (zero salinity)
  - WWTPs added for tracers
  - Meteorology
- Initial conditions (inside the model domain)

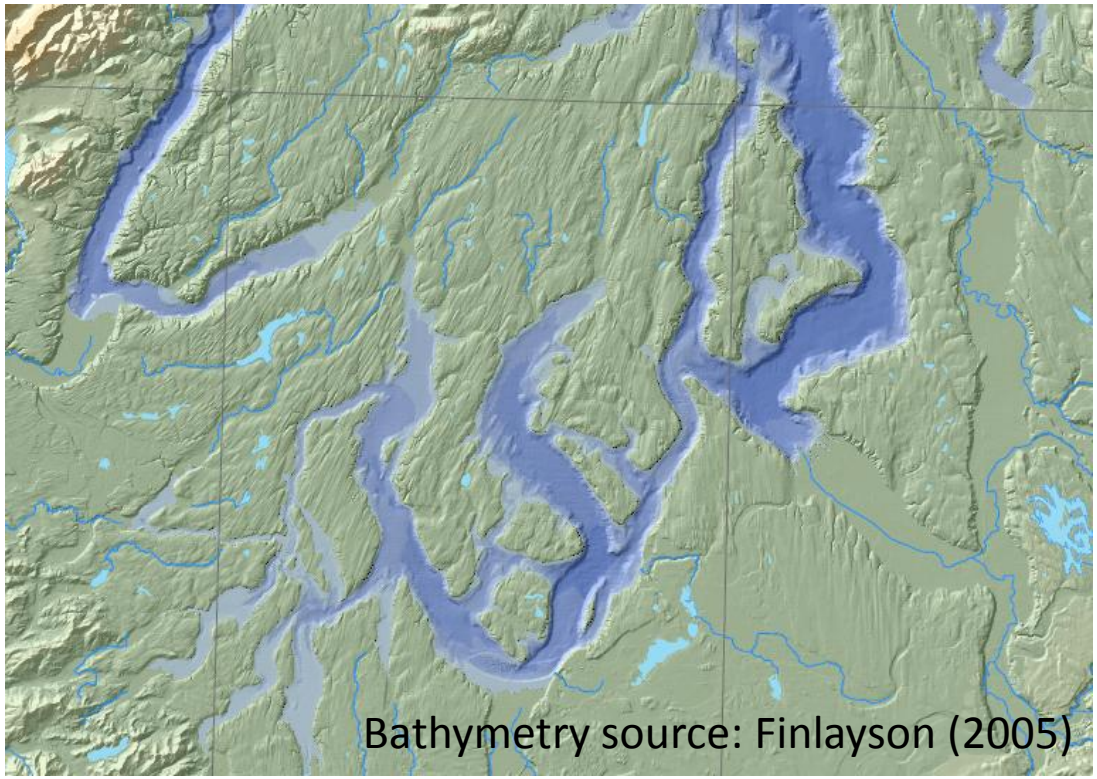


Circulation model development

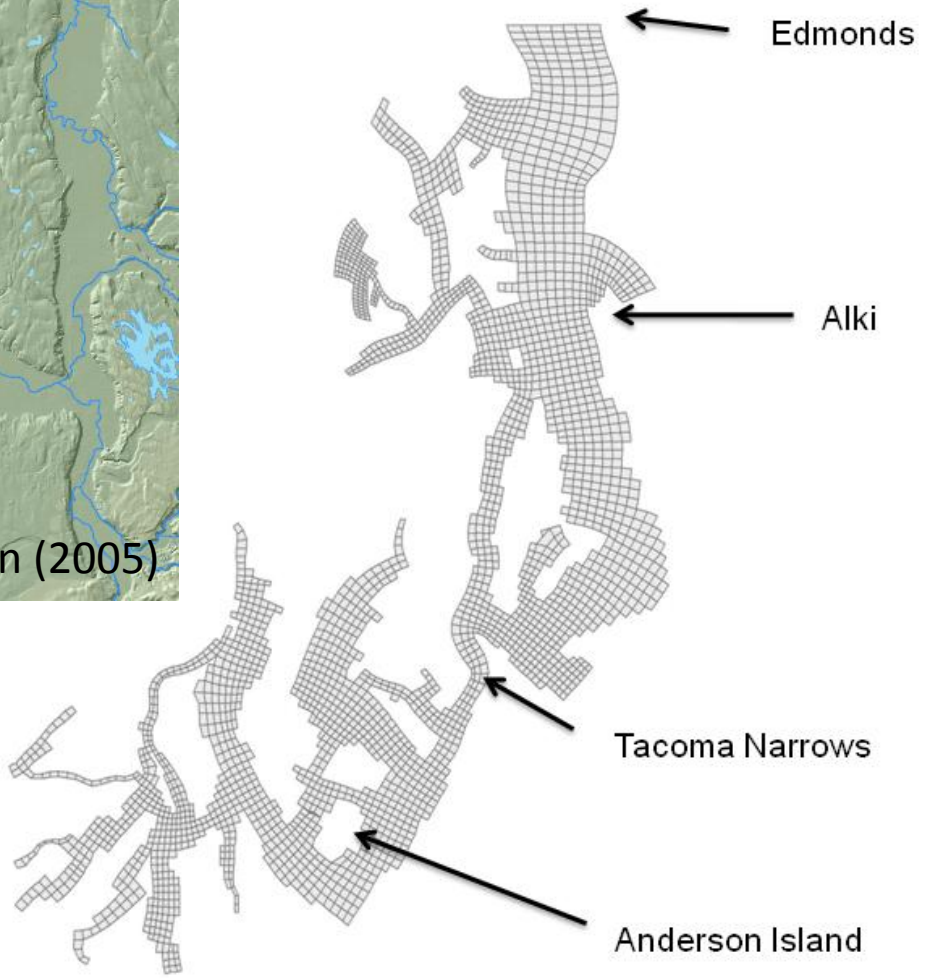
- Calibration and confirmation
  - Water surface elevations
    - PSTides
    - NOAA tide gauge
  - Surface and near-bottom temperature and salinity
    - Geographic differences
    - Time series
  - Profiles of temperature and salinity
  - Current velocities



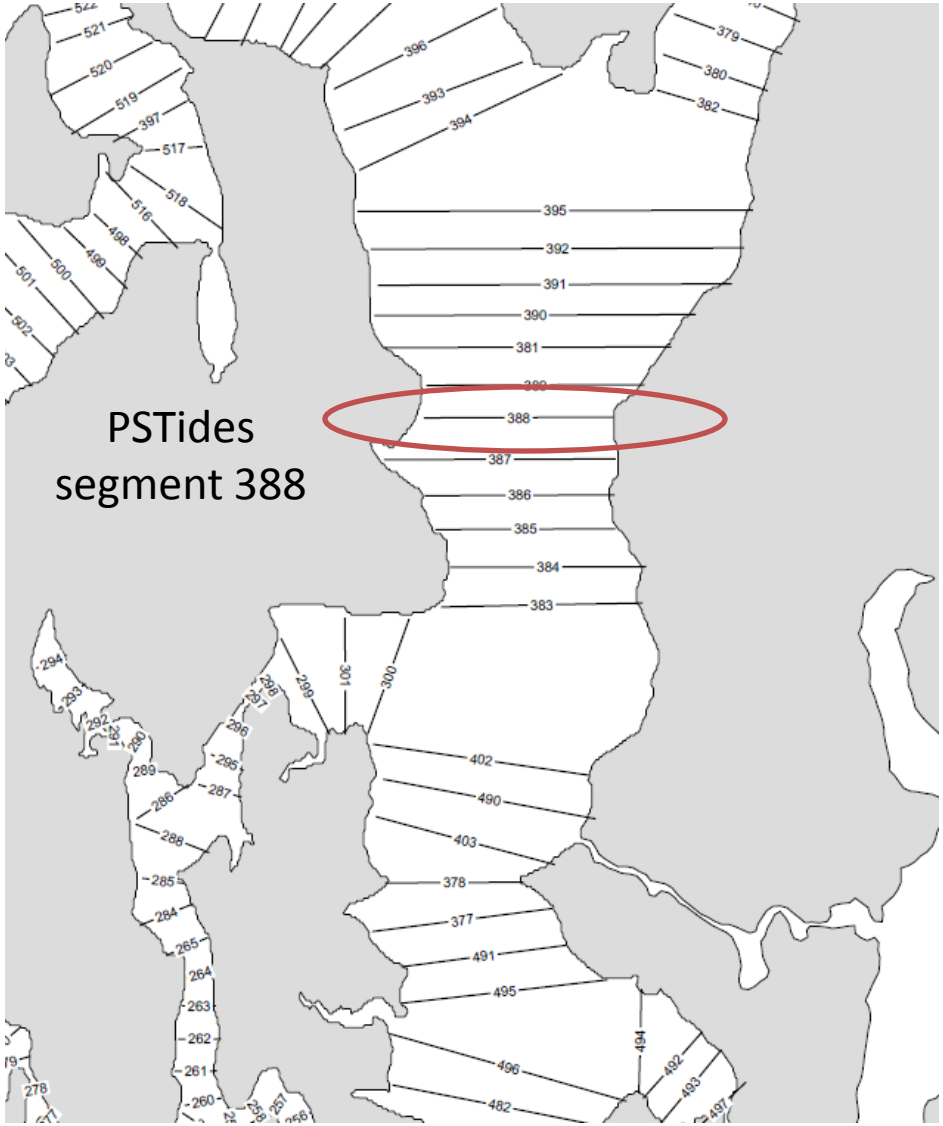
3-D Circulation Model



- 2623 grid cells
- 500 m X 500 m (nominal)
- Up to 17 layers



Northern boundary conditions



<u>Water surface elevations:</u>

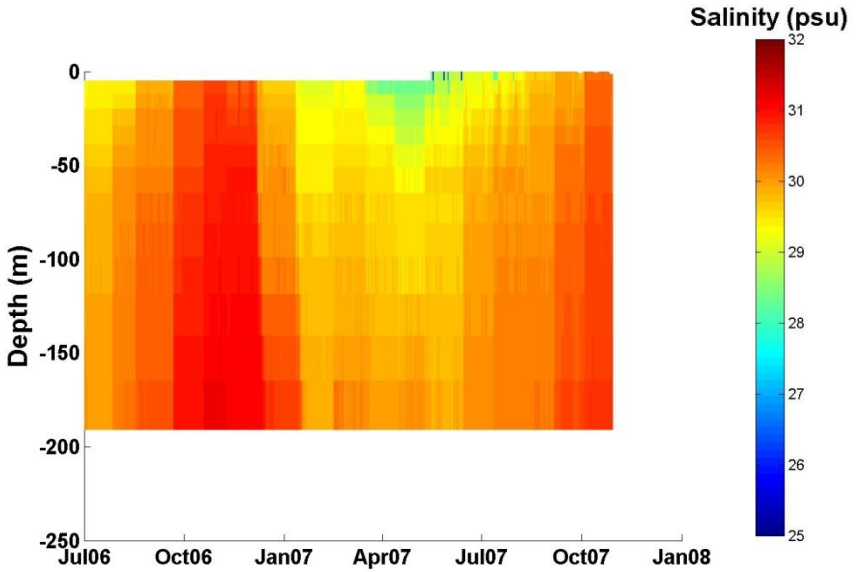
PSTides

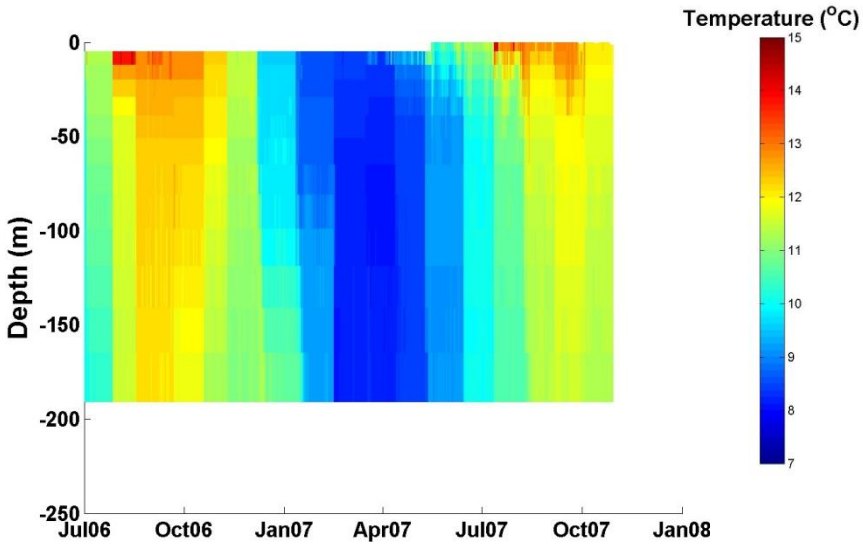
- Specialized tidal model
- Detailed predictions not available from other sources
- Selected segment closest to the northern (Edmonds) boundary

Northern boundary conditions

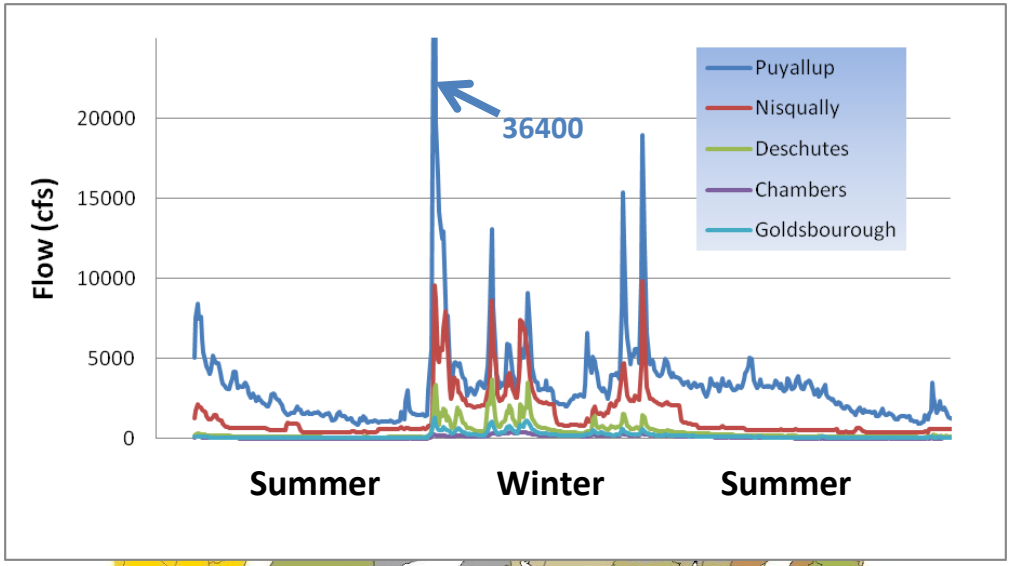
Temperature and salinity

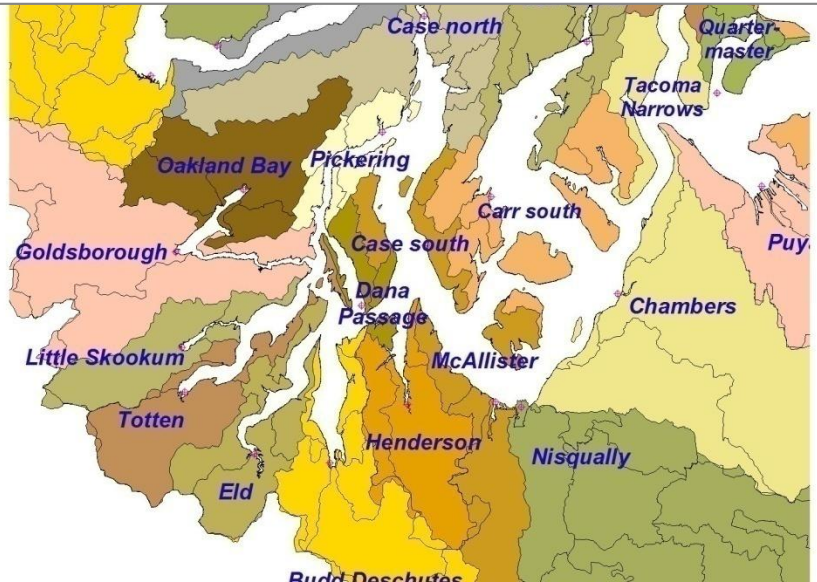
- Monthly marine data (King County DNR)
- Interpolated between monthly visits
- Considered other sources
  - Princeton Ocean Model
  - ORCA (Hood Canal)
  - Would need assumptions





River Inflows





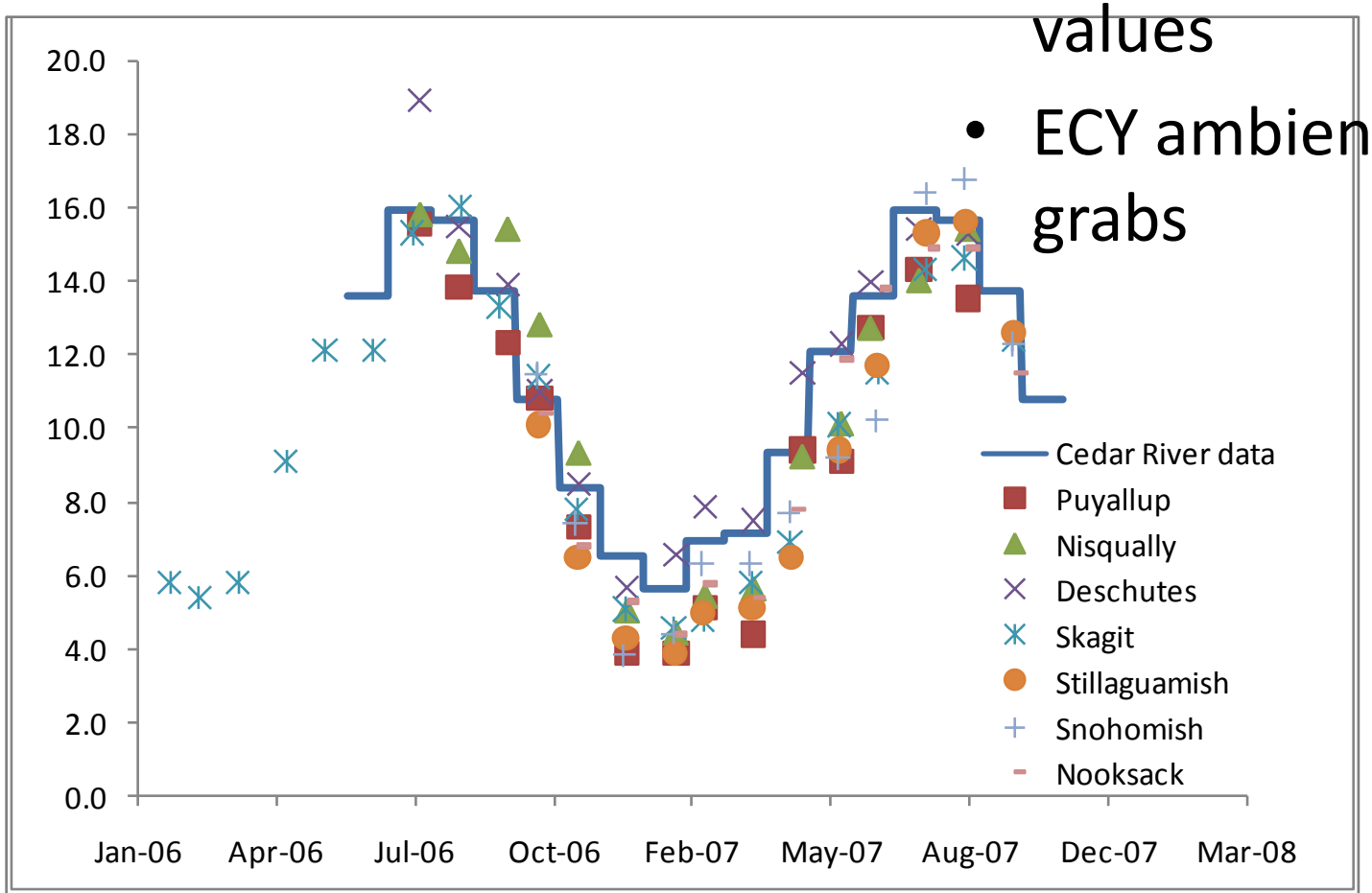
Measured flows at USGS stations

Extrapolate to subwatersheds using tributary area and precipitation factor

- Interactive tool for exploring data: ftp://www.ecy.wa.gov/Sackmann/psdom_2009_q1.html

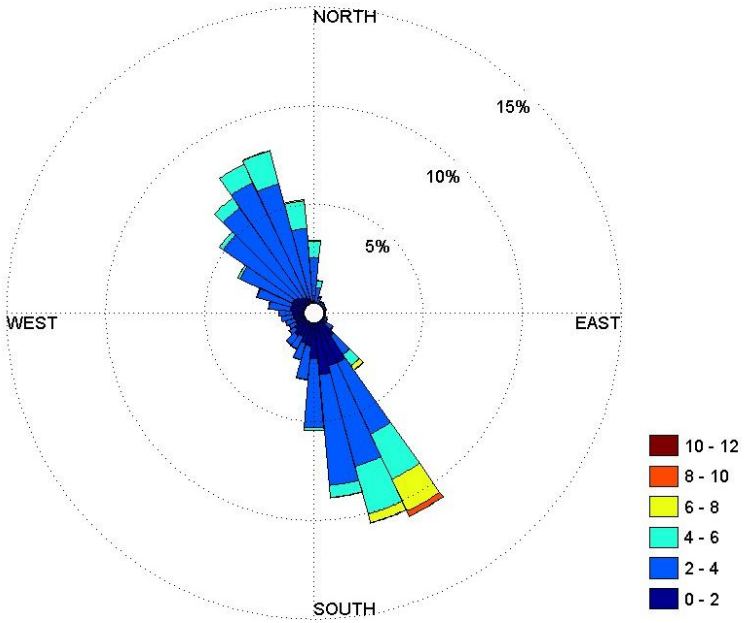
River temperature (salinity = 0)

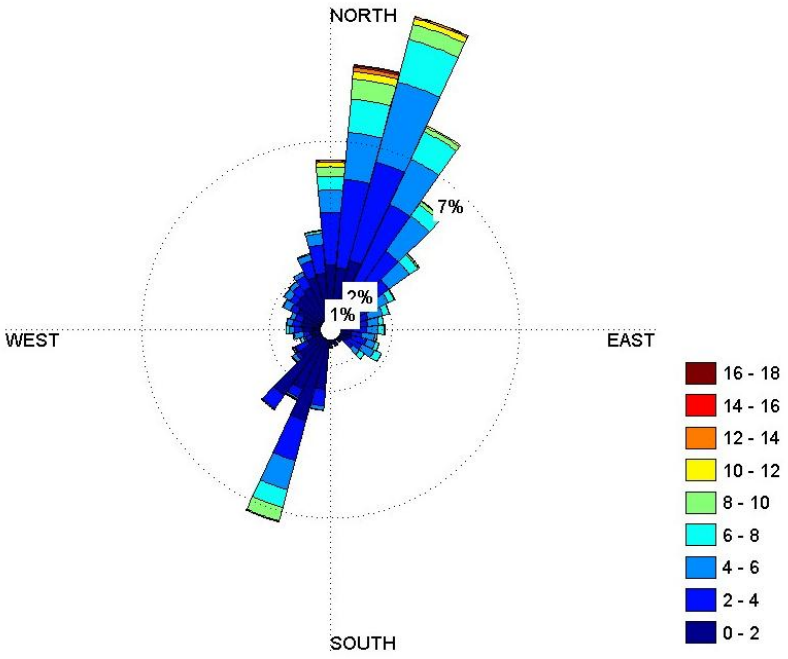
- Cedar River (USGS) data for year round daily values
- ECY ambient monthly grabs



Meteorology

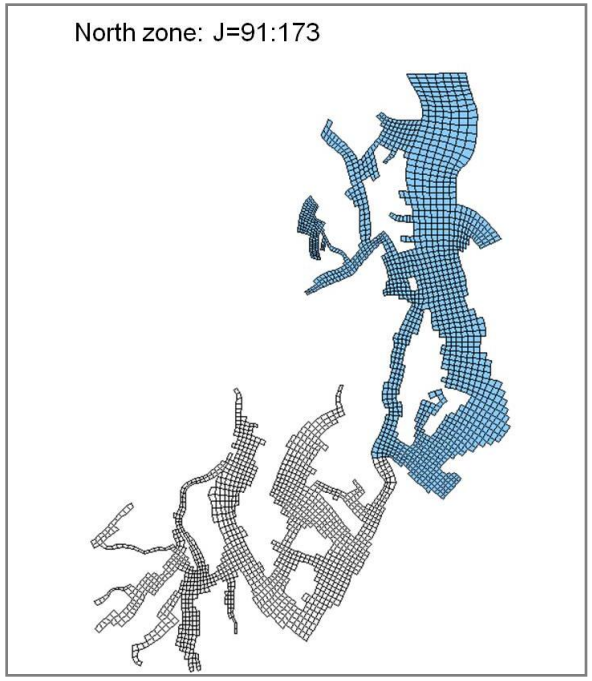
- SeaTac and McChord, assigned to SPS, CPS
  - Wind, precipitation
- UW solar radiation data

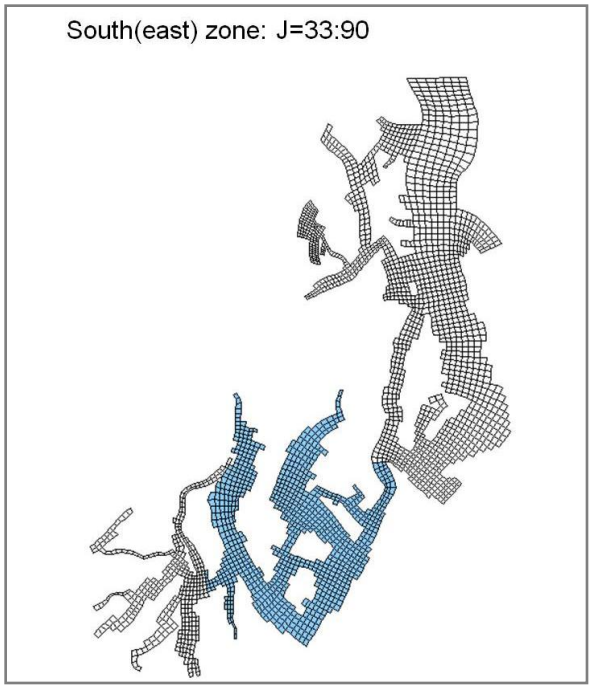


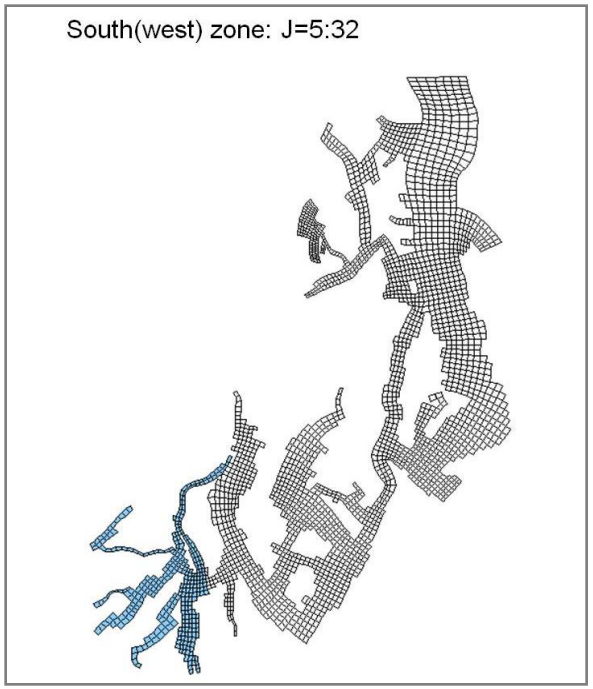


Initial conditions

- June 2006 marine data assigned to each of three regions

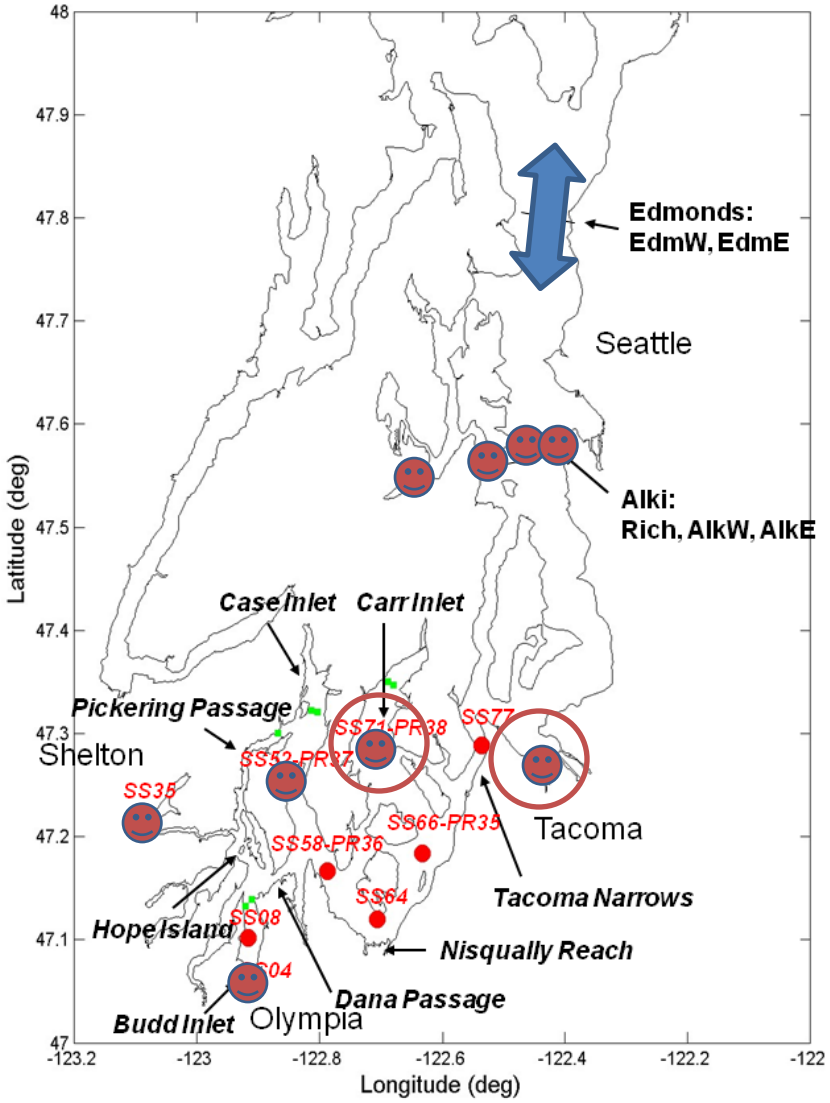




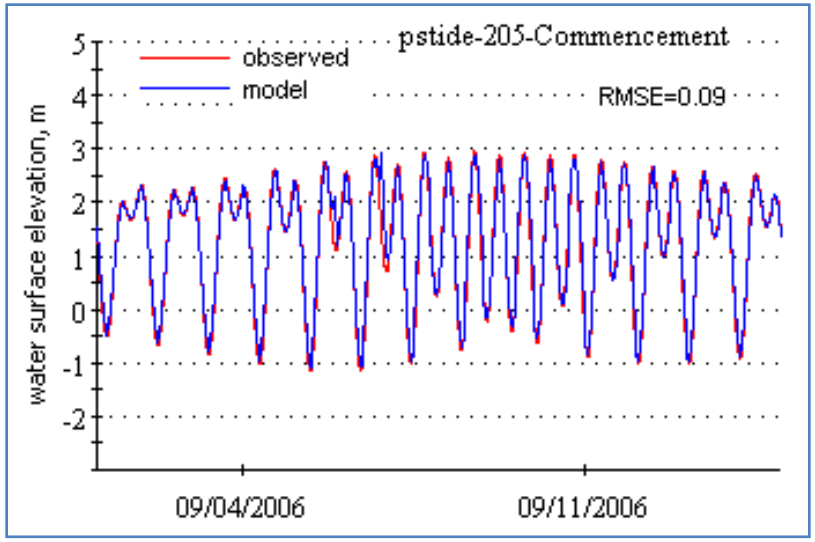


Calibration and confirmation: water surface elevations from PSTides

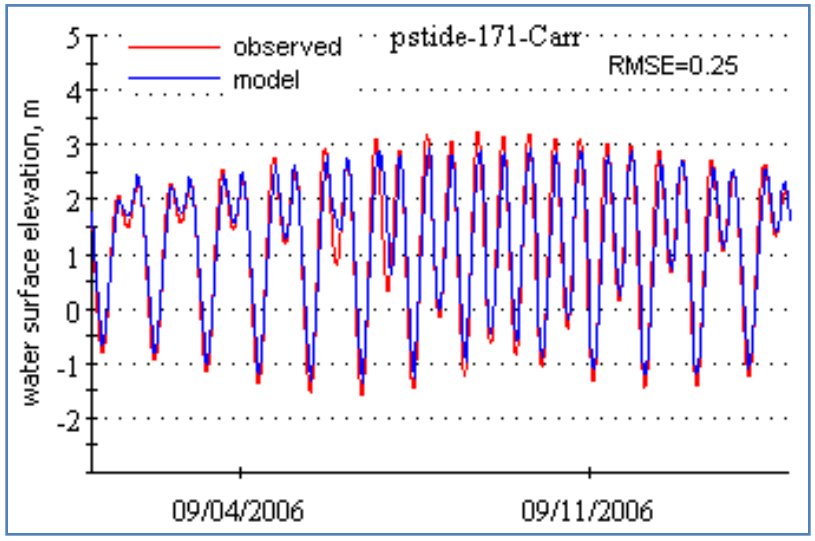
- Tuning parameters:
  - Grid element volumes
  - Bottom friction
- Revised bathymetry to match chart volumes:
  - Tacoma Narrows
  - Budd Inlet
  - Hammersley Inlet
  - Pickering Passage



Water surface elevations



- Commencement Bay (top) represented well, with low RMSE (9 cm)

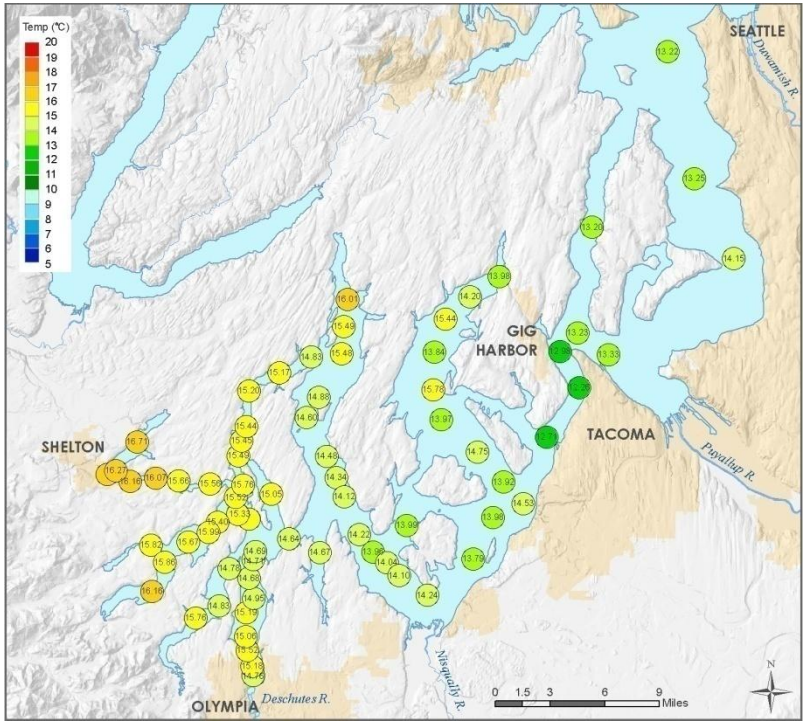


- Carr Inlet (west of Tacoma Narrows) has high RMSE (25 cm)
  - Affected by Tacoma Narrows

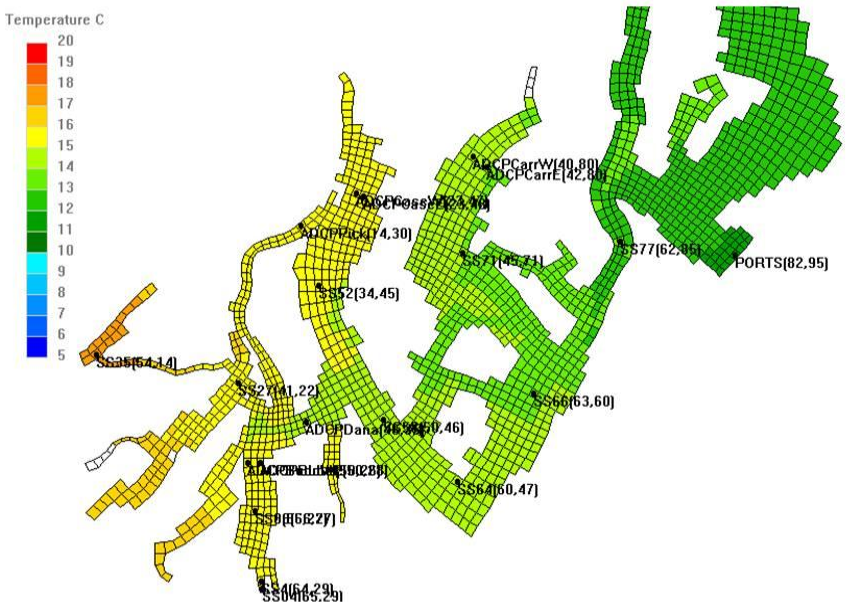
Calibration and confirmation: surface and near-bottom temperature and salinity

**DRAFT RESULTS*(earlier model run)*

- September 2006 data



- September 2006 model



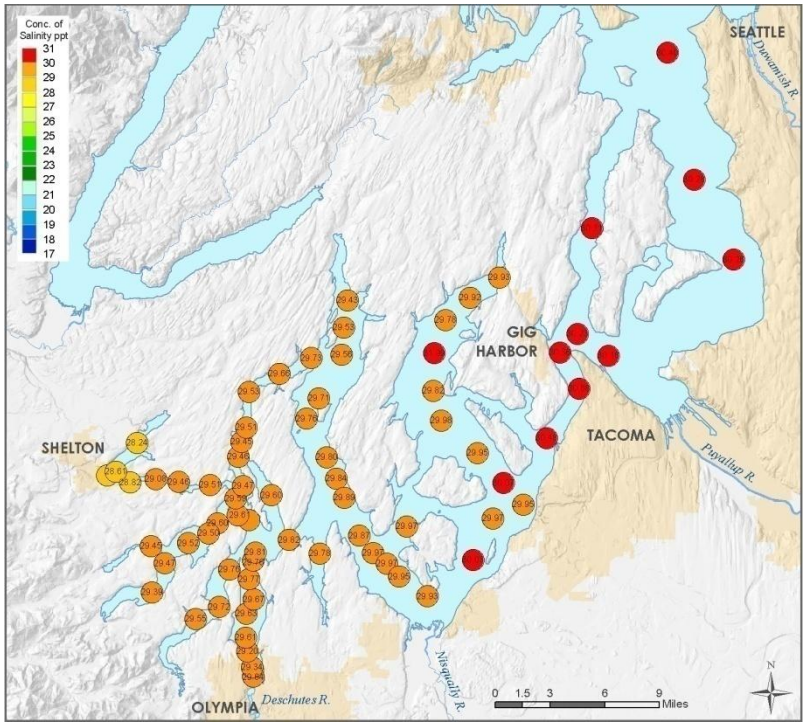
Temperature (°C)

Results are good if the colors are alike

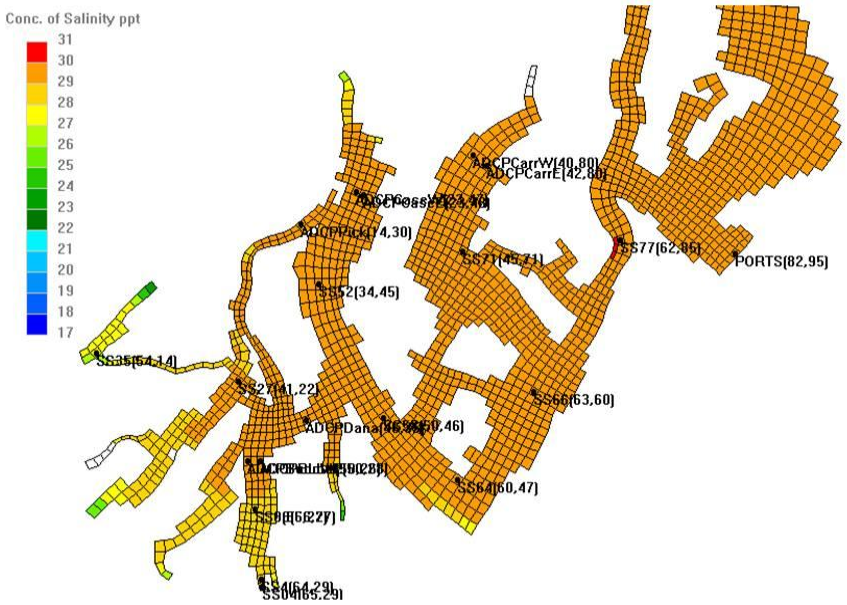
Calibration and confirmation: surface and near-bottom temperature and salinity

**DRAFT RESULTS*(earlier model run)*

- September 2006 data



- September 2006 model



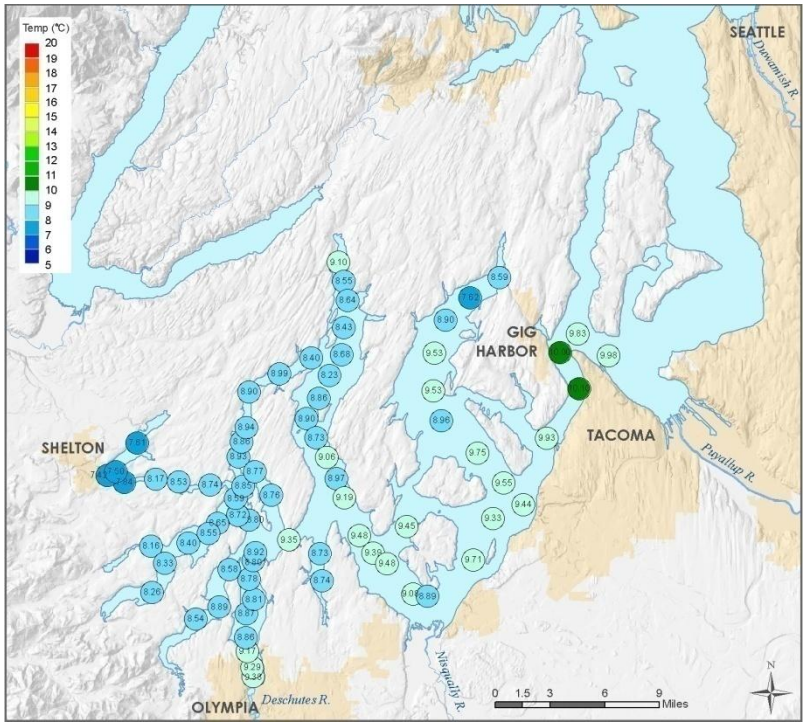
Salinity (psu)

Results are good if the colors are alike

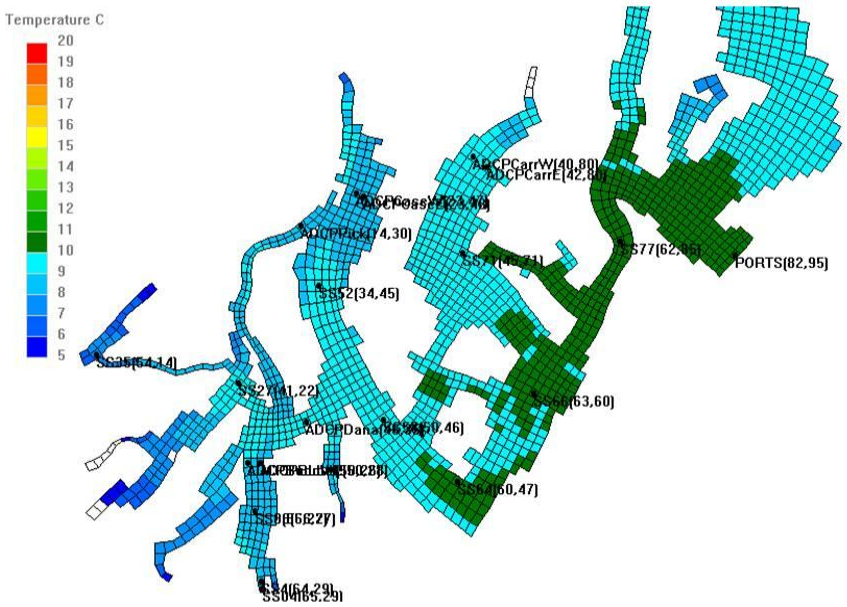
Calibration and confirmation: surface and near-bottom temperature and salinity

**DRAFT RESULTS*(earlier model run)*

- December 2006 data



- December 2006 model



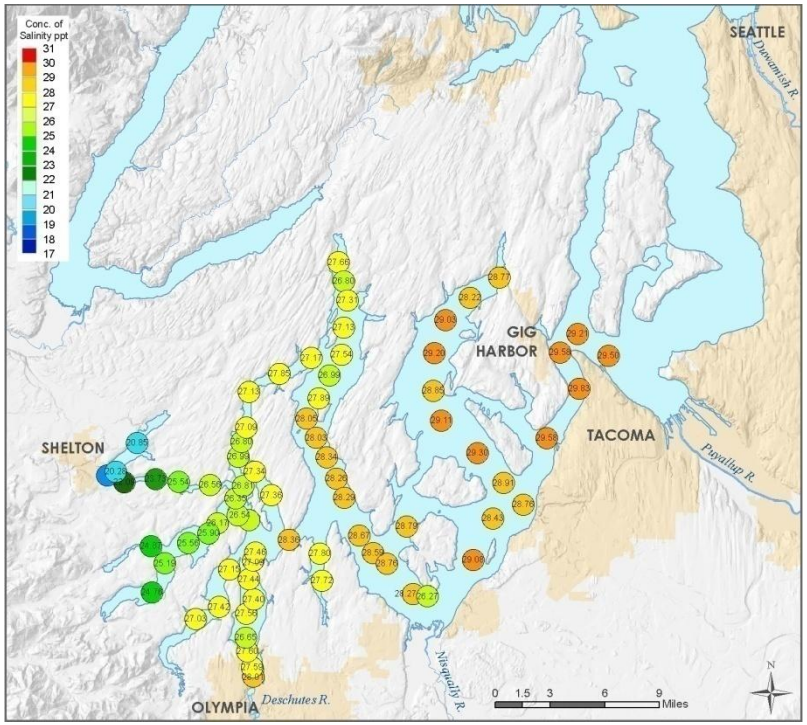
Temperature (°C)

Results are good if the colors are alike

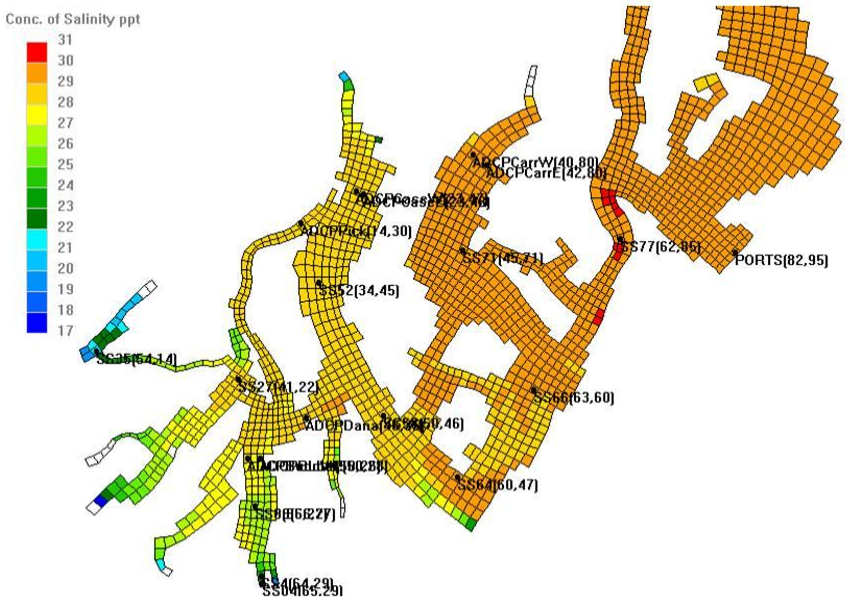
Calibration and confirmation: surface and near-bottom temperature and salinity

**DRAFT RESULTS*(earlier model run)*

- December 2006 data



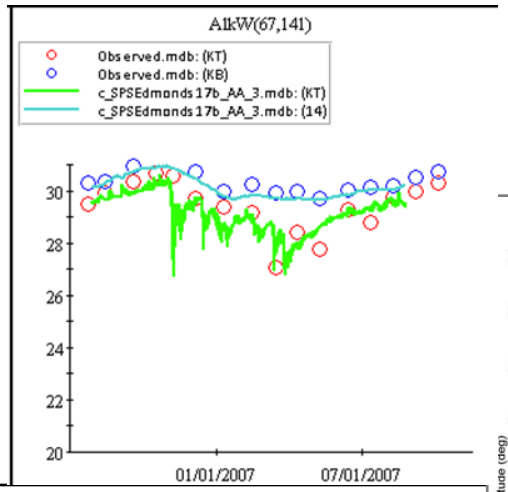
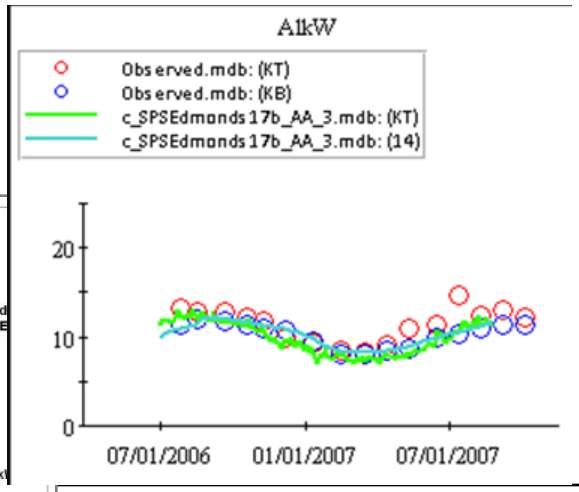
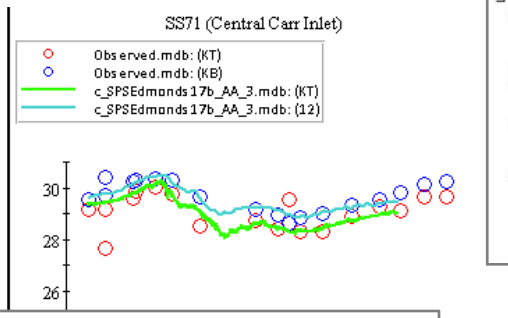
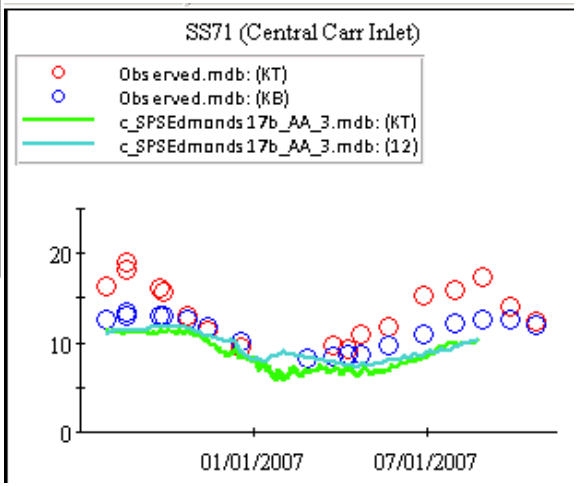
- December 2006 model

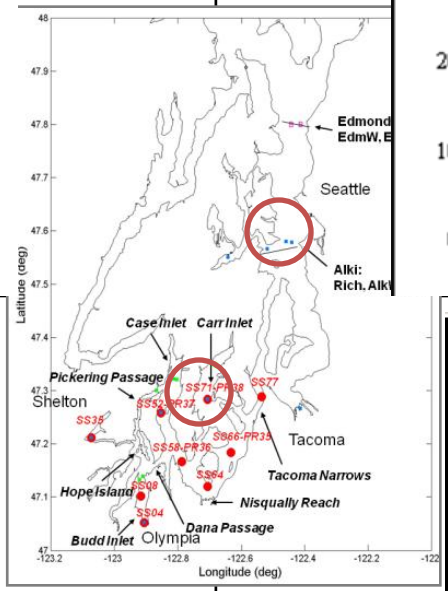


Salinity (psu)

Results are good if the colors are alike

Calibration and confirmation: surface/bottom temperature and salinity time series

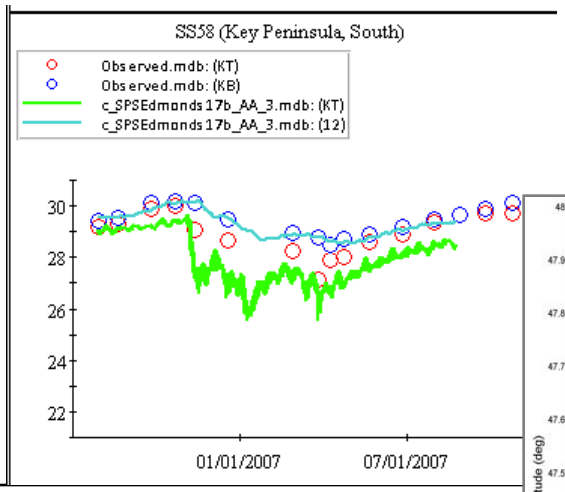
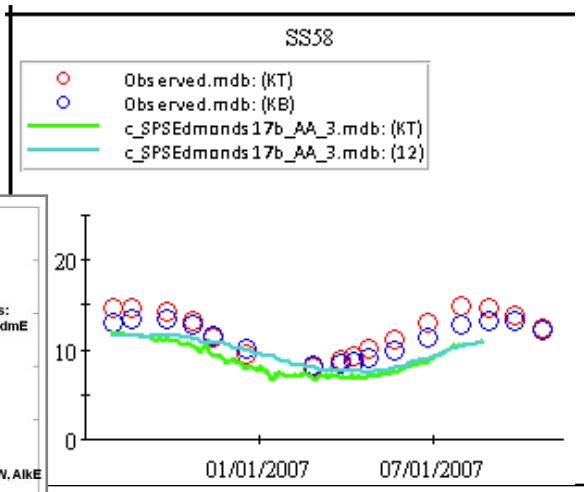
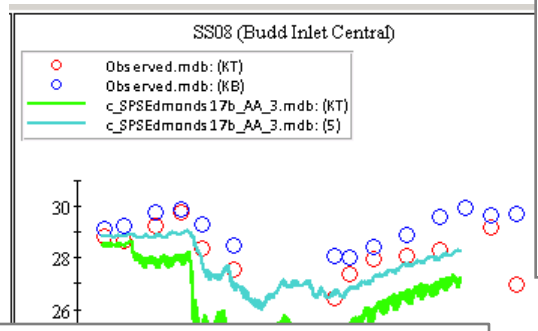
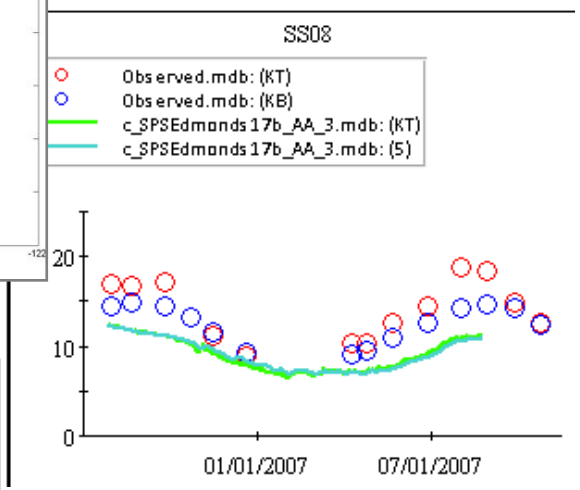
	Salinity (psu)	Temperature (°C)
Alki West		
Central Carr Inlet		

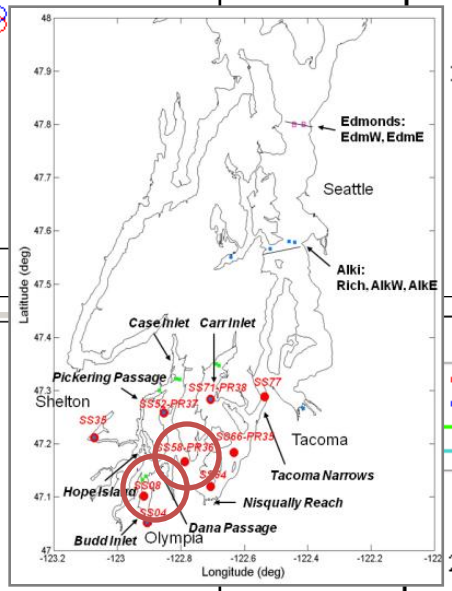


Results are good if dots plot on lines

Surface
Near-bottom

Calibration and confirmation: surface/bottom temperature and salinity time series

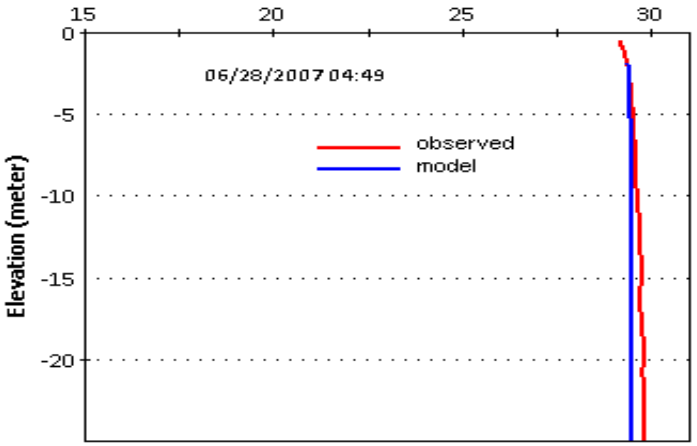
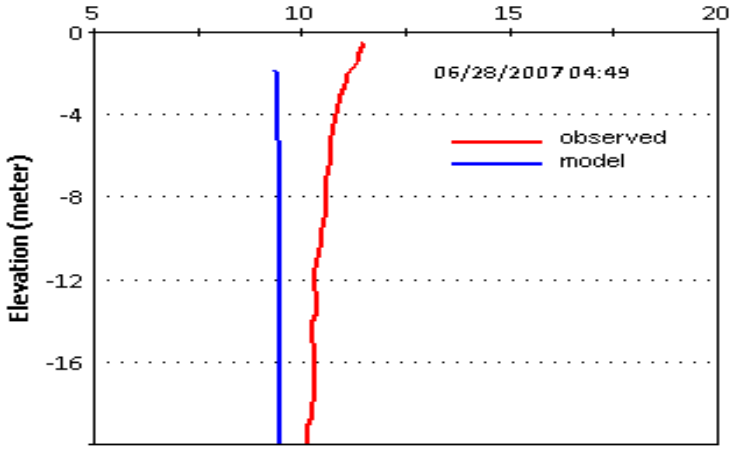
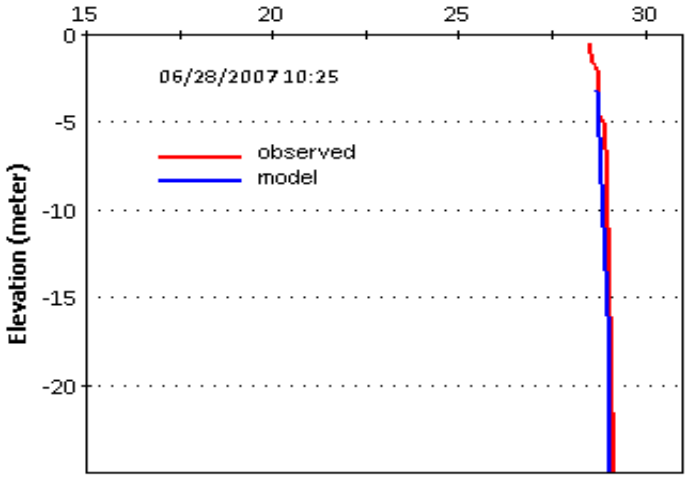
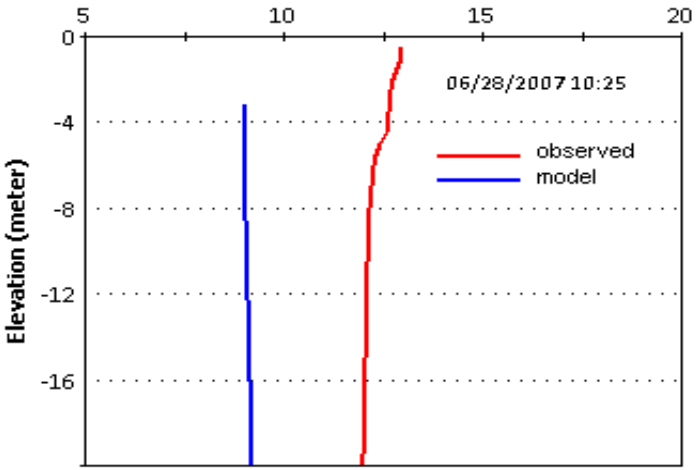
	Salinity (psu)	Temperature (°C)
South of Key Peninsula		
Central Budd Inlet		



Results are good if dots plot on lines

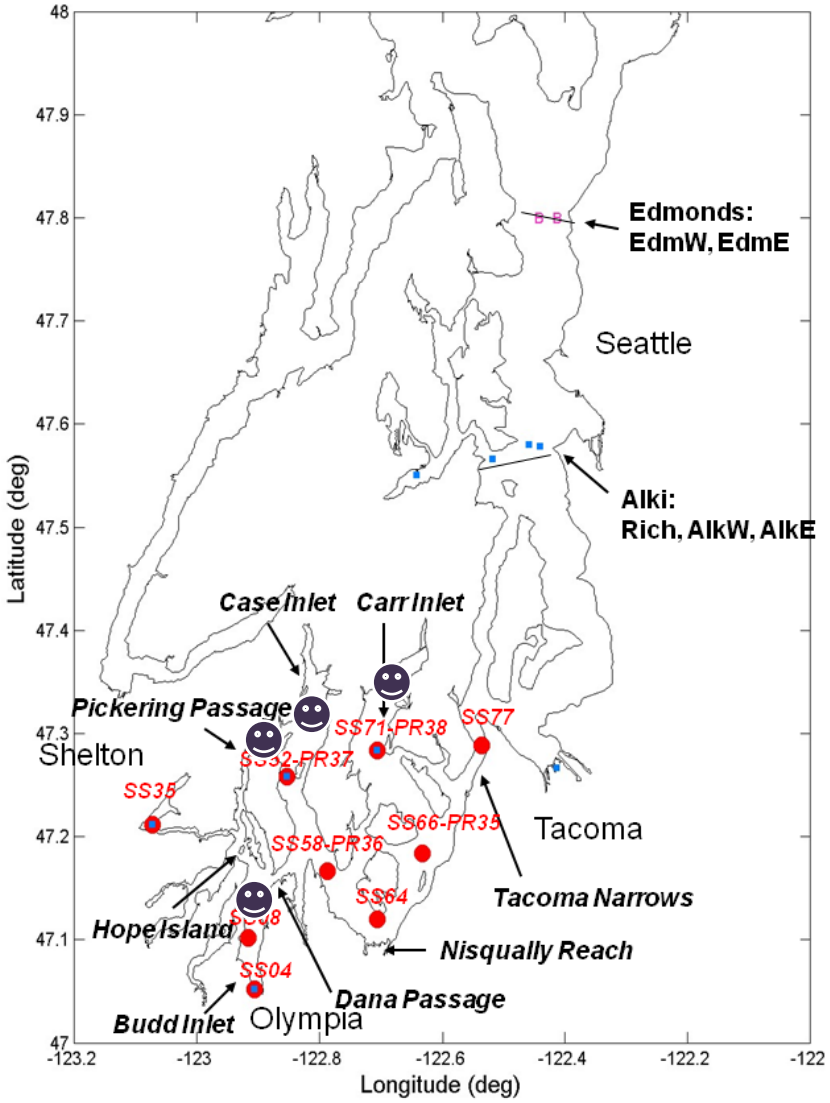
Surface
Near-bottom

Calibration and confirmation: temperature and salinity profiles

	Salinity (psu)	Temperature (C)
Tacoma Narrows		
North of Ketron		

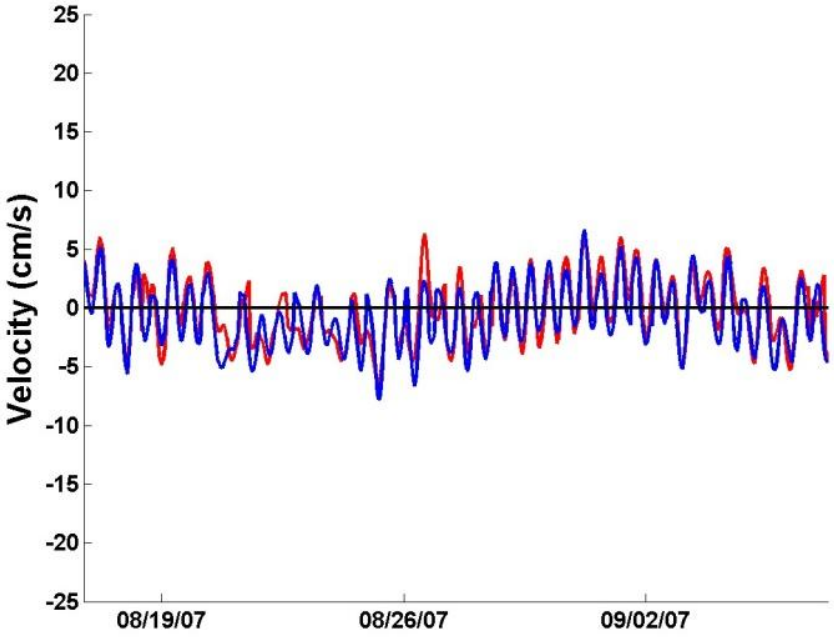
Calibration and confirmation: current velocities

- 2007 transects
- Fall 2007 for two weeks
  - Budd Inlet
  - Case Inlet
  - Carr Inlet
- Fall 2006 at Pickering Passage

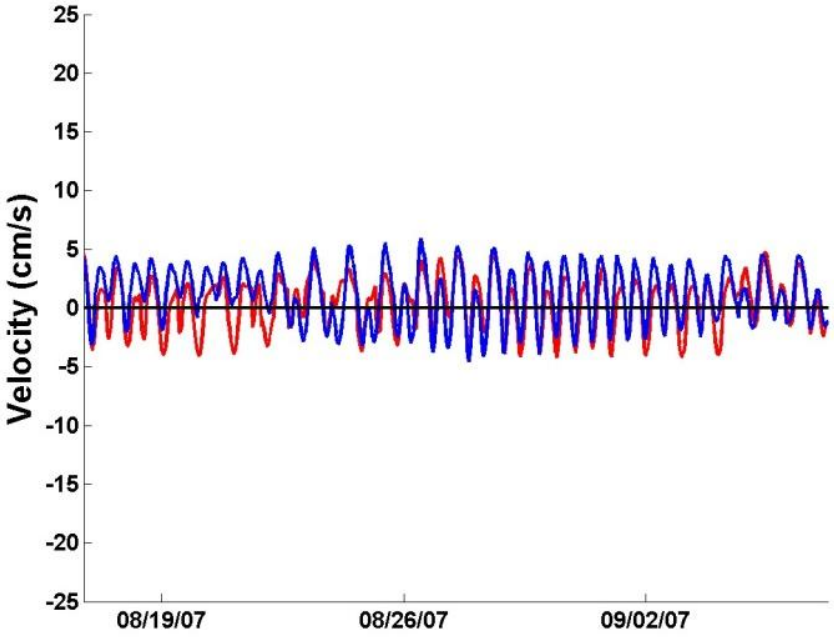


Calibration and confirmation: Carr Inlet current velocities

- Data (west)



- Model (west)



Calibration and confirmation status and goals

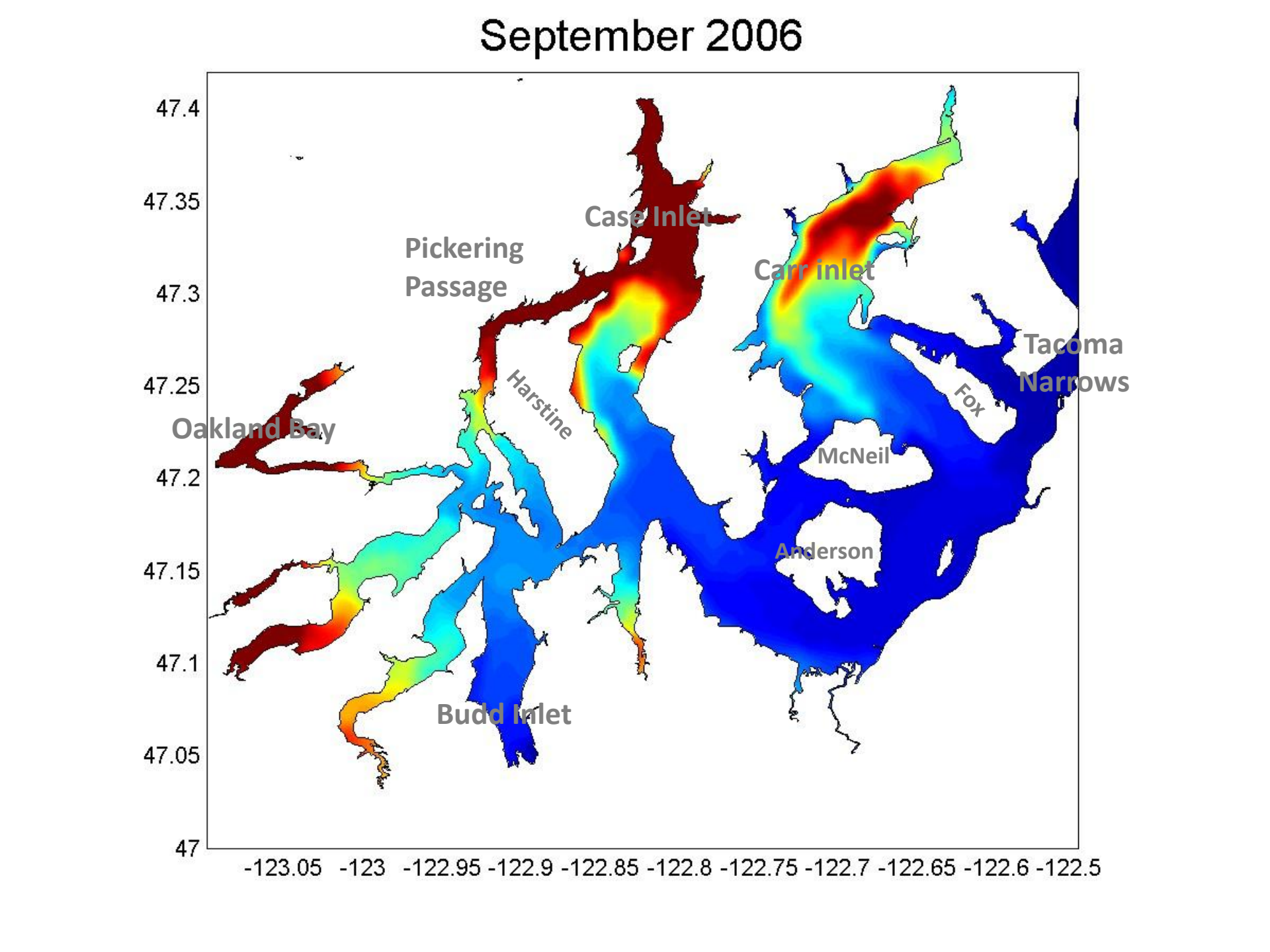
- Water surface elevations must be well described throughout the model domain (RMSE < 10 cm)
  - Lowest error: Central Puget Sound
  - Highest error: Oakland Bay (*needs work*)
- Surface and near-bottom salinity and temperature must capture geographic and spatial variability
  - Salinity good; *temperature needs work*

Calibration and confirmation status and goals

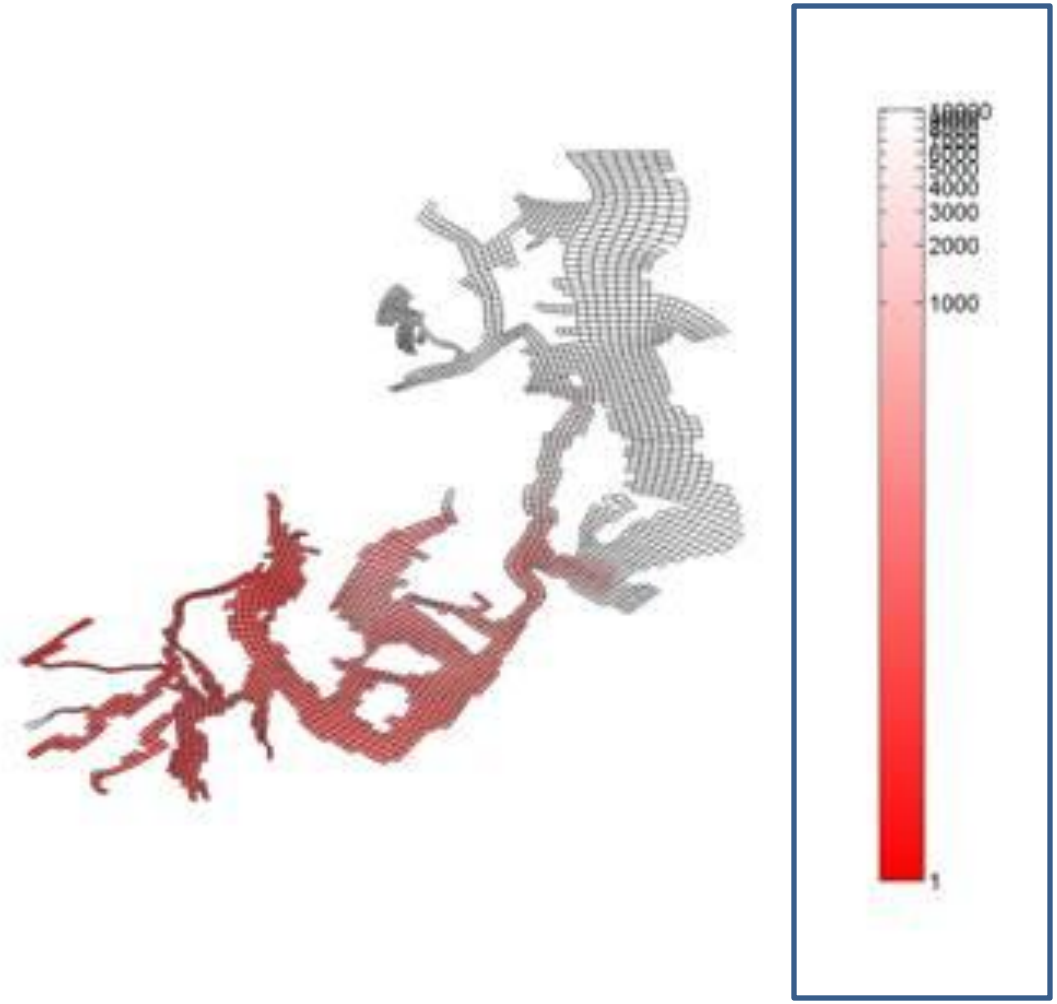
- Profiles must capture geographic and temporal variation
  - Salinity OK; *temperature needs work*
- Current velocities must match phasing (timing) and amplitudes
  - *Needs work*

- *Close, but not quite a calibrated model*

Example future model output (not final yet)


September 2006
47.4
47.35
47.3
47.25
47.2
47.15
47.1
47.05
47
-123.05
-123
-122.95
-122.9
-122.85
-122.8
-122.75
-122.7
-122.65
-122.6
-122.5
Case Inlet
Pickering Passage
Carr inlet
Tacoma Narrows
Harstine
Fox
Oakland Bay
McNeil
Anderson
Budd Inlet

Example dye releases



Can we rule in or rule out Central Puget Sound sources?

- Circulation model?
  - Maybe, but answer could very well be in a gray area (not black or white)
- Water quality model
  - Beginning development now
  - Later 2009 for indications of area of influence

Next steps

Water quality model development

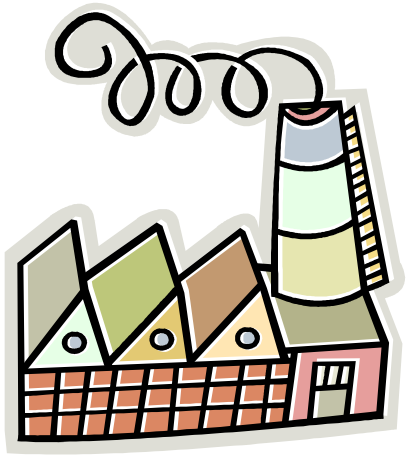
- Builds from the circulation model
- Developing boundary conditions
  - Rivers and wastewater treatment plants
  - Northern boundary (nutrient and DO profiles)
- Compare against measured data
  - Calibration and confirmation
- Scenarios

Apply model to various what-if scenarios

Input Data

Model Development

What-if Scenarios



What if nitrogen loads decrease?

Will South Sound DO levels…

… improve markedly?

… remain low?

Project milestones

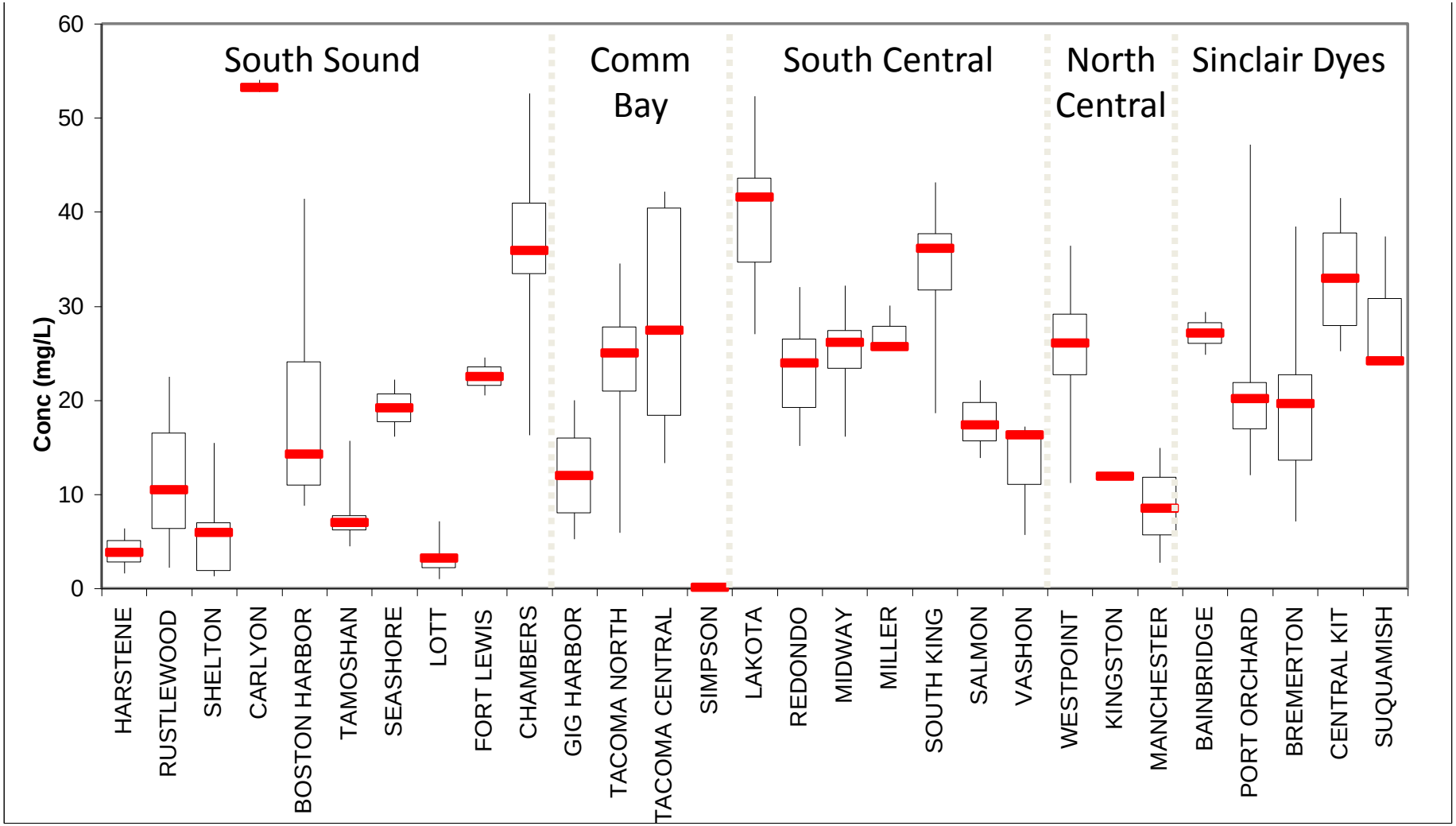
- Draft circulation model report — June 2009
- Water quality model development — Ongoing
- Water quality model report — Dec 2009
- Scenarios — Ongoing
- Final project report — June 2010

- **NEP funding overview (model audits, scenarios)**
- **June 2010: How much of an effect are human nutrient sources having on South Puget Sound?**


Questions?

If needed for questions

WWTP DIN concentrations



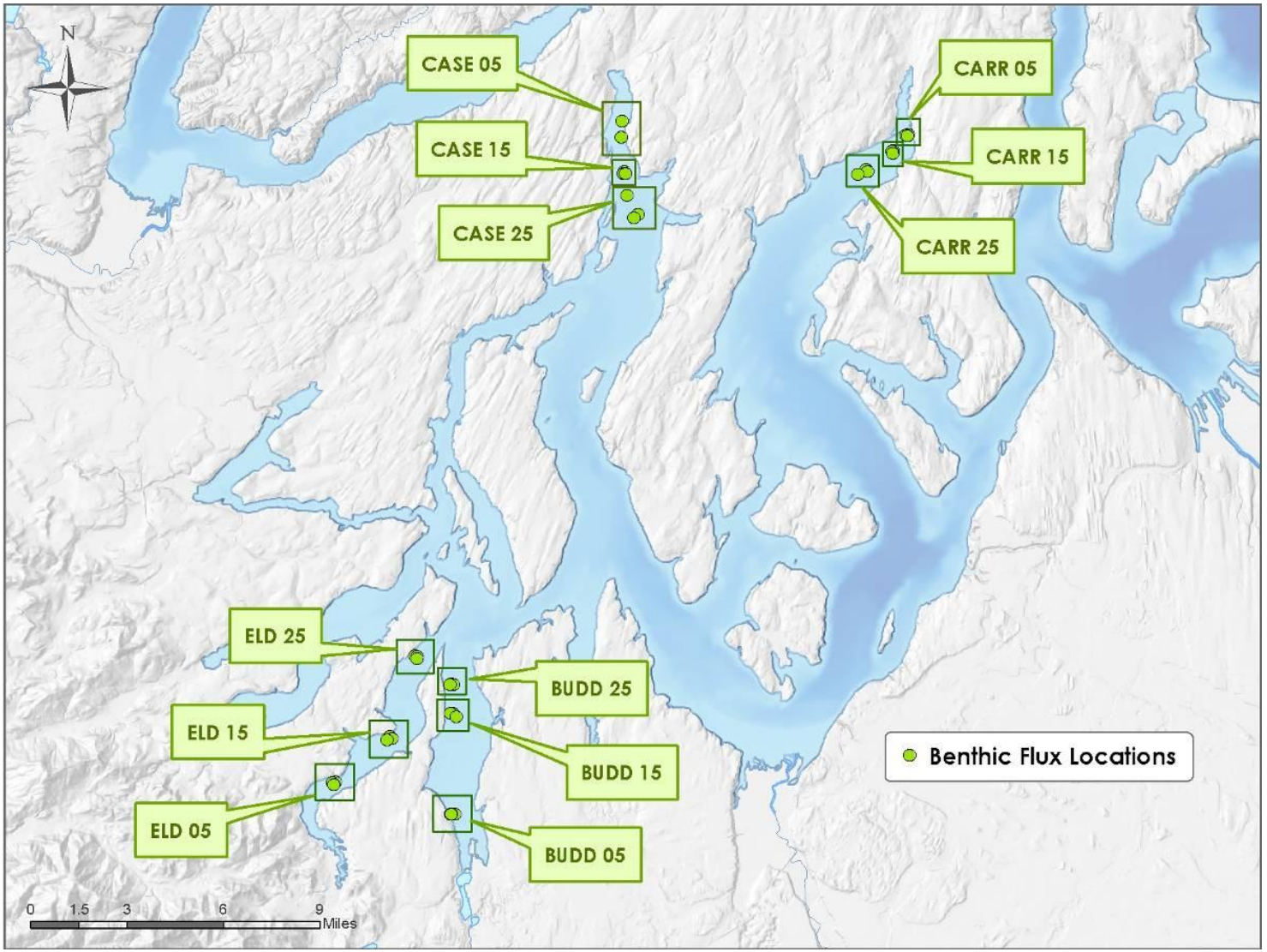
Sediment DIN flux

- World Flux Database
  - Mean: 0.040 g-N/m^2-d (NH4)
- Chesapeake Bay
  - Mean: 0.064 g-N/m^2-d (DIN)
- Budd Inlet Scientific Study

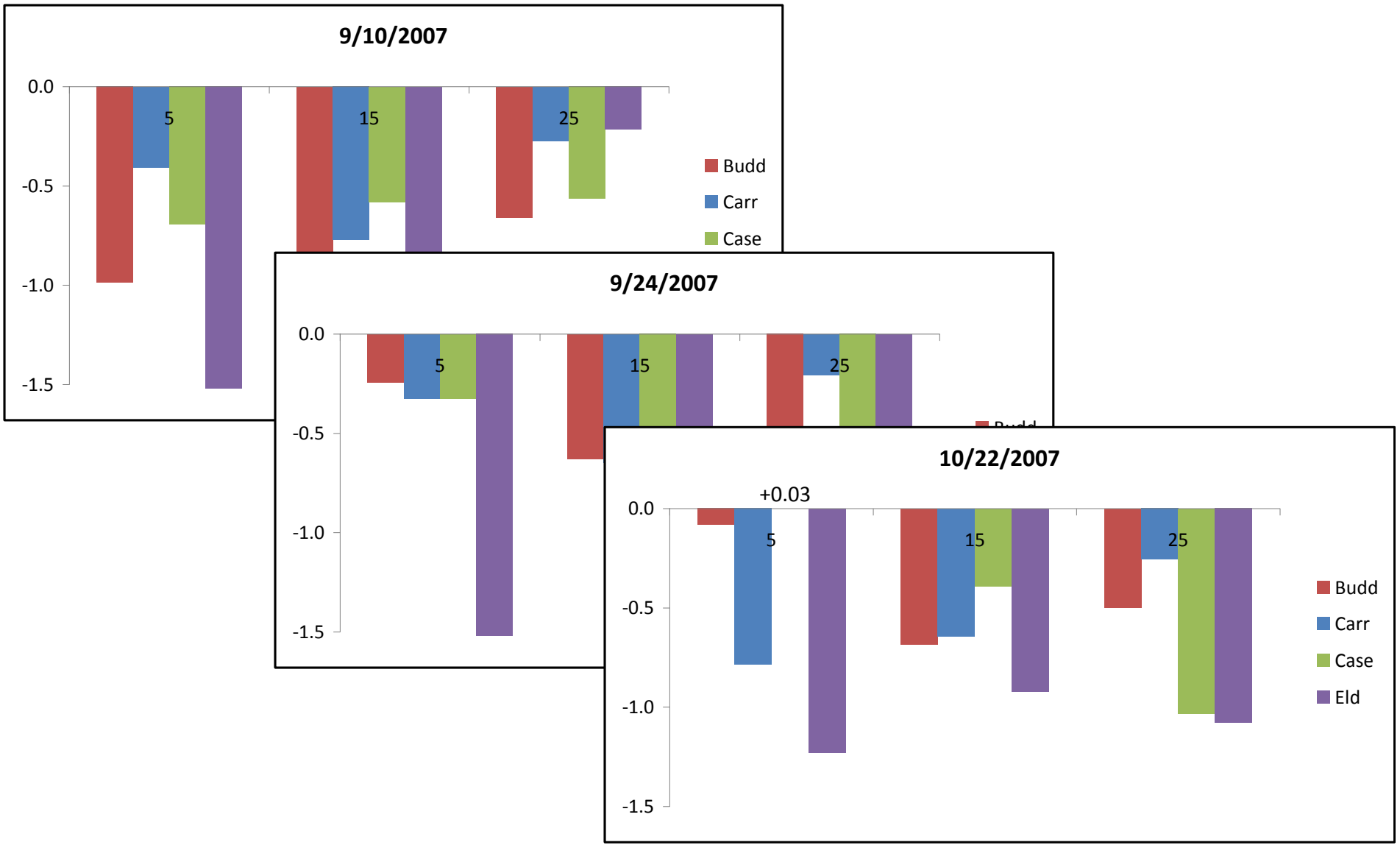
Sediment flux estimates

- Budd Inlet
  - 1998 Budd Inlet Scientific Study (annual and seasonal)
    - Annual: 326 metric tons-N/yr or 890 kg-N/d
    - Late summer: 2400 kg-N/d
  - Present study
    - Late summer: 1100 kg-N/d (Budd Inlet)
    - WWTPs: 2800 kg-N/d (South Sound)
    - Tribs: 2700 kg-N/d (South Sound)
  - ***Sediments are an important nutrient reservoir***

Sediment flux locations



Sediment oxygen demand



Sediment DIN loads